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Environment

Niagara River Mussel Biomonitoring Program, 1997

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FOREWORD

The data generated by the1997 Niagara River Biomonitoring Survey augment other federal and provincial Niagara River Toxics Management Plan programs by providing information on contaminants in the river between Fort Erie and Niagara-on-the-Lake. The Niagara River mussel biomonitoring survey, conducted by the Ontario Ministry of Environment, has been ongoing since 1980 (Kauss 1987; Kauss and Angelow 1988; Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997).

Information provided by this study is part of an overall program to assess long-term trends in contaminant loadings from selected sources along the Niagara River.

ACKNOWLEDGEMENTS

The 1997 Niagara River Biomonitoring study was conducted by the Water Monitoring Section (formally named the Surface Water Section) of the Environmental Monitoring and Reporting Branch of the Ontario Ministry of Environment (MOE).

The author expresses appreciation to: Jörgen Fleischer, Duncan Boyd, Peter Kauss and Alan Hayton of the Environmental Monitoring and Reporting Branch and to Wally Rozenberg of West Central Region for their constructive reviews of the report, and to Keith Somers (Standards Development Branch) for statistical advice and assistance.

The author would also like to acknowledge the efforts of the crew chief Greg Hobson, summer student Tamara McFarland, and field contractor Brian Thorburn for the field work. The author further acknowledges the efforts of the Biomaterials and Sediment Unit and Dioxin and Furan Unit of the MOE Laboratory Services Branch for the analysis of these samples.

The map of the Niagara River used in Figure 1 was originally provided by Environment Canada for the 1995 mussel biomonitoring report. The Canadian portion of the shoreline was digitized by Geomatics International in 1992 as part of the International Joint Commission Water Levels Reference Study. The U.S. shoreline was digitized by Environment Canada from NOAA Hydrographic maps in 1993. Major and minor rivers were obtained from the Ecosystem Health Division of Environment Canada.

SUMMARY

Since 1980 the Ontario Ministry of Environment (MOE) has been committed to both routine and specialized biomonitoring of contaminants in the Niagara River using caged mussels (*Elliptio complanata*) as part of Ontario's commitment to the Niagara River Toxic Management Plan. Mussels were deployed on the American as well as the Canadian side of the river. These studies have provided information on suspected contaminant sources and source areas in the river between Fort Erie and Niagara-on-the-Lake (Kauss 1987; Kauss and Angelow 1988; Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997).

In 1997, two complementary studies were initiated by the MOE:(a) the routine deployment of caged mussels at 32 stations on the Canadian and American sides of the river for 21 days of exposure, and (b) a long term deployment of mussels up to four months at four stations. Mussels were retrieved after the designated period of deployment and the tissues were analysed for organochlorine pesticides, total polychlorinated biphenyls (PCBs), chlorinated benzenes, polycyclic aromatic hydrocarbons (PAH) and polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF).

Twenty-one day exposure findings

Analytical results from the caged mussel study were similar to those in previous years of monitoring since 1980. Organochlorine pesticides, chlorinated benzene compounds and PCBs were not detected in mussels introduced on the Canadian side of the river, with the exception of trace concentrations of p,p'-DDE (metabolite of the pesticide DDT).

Organochlorine pesticides were detected sporadically at several stations on the U.S. side of the river at concentrations similar to results from past surveys. Mirex was detected in mussels deployed at sites associated with the Occidental Chemical Corporation. PCBs and chlorinated benzene compounds were detected at almost all stations. PCBs were detected at similar concentrations at most sites making it difficult to identify specific point or non-point sources along the Tonawanda Channel and in the lower Niagara River. The most frequently detected chlorinated benzenes were; hexachlorobenzene, pentachlorobenzene and 1,2,3,4-tetrachlorobenzene. The highest chlorinated benzenes were detected at the Occidental sewer 003 and at the Pettit Flume cove.

Tissue concentrations of almost all parameters were below the detection limit at the 102nd Street Landfill site when mussels were deployed after remedial activities were completed. This was in contrast to high concentrations of these compounds previously detected in caged mussels. Dioxins and furans in mussels deployed at 102nd Street Landfill were low

and reflect the success of the site remediation and removal of contaminated sediment. Dioxins and furans were not detected in the sediment sample collected from the site.

At Bloody Run Creek concentrations of dioxins and furans in exposed shoreline (bank) sediment although lower than pre-remediation concentrations, were still high relative to sediment concentrations throughout the Great Lakes basin including some of the most contaminated sites that have been identified by MOE. Characteristic of the congener/isomer patterns for Bloody Run Creek all the tetra-dioxin was in the form of 2,3,7,8-tetrachlorodibenzo-p-dioxin which is the most toxic form of dioxin (45,000 pg/g). This sediment sample was collected from the shoreline of the Niagara River which is routinely underwater as levels fluctuate daily to maintain the operation of the hydro generating stations. The fluctuating water levels make the sediment susceptible to erosion. The presence of dioxins and furans in mussels at this site suggest that these compounds were bioavailable to the Niagara River.

High concentrations of dioxins and furans were detected in mussels and sediment from the Pettit Flume inlet cove. The source of the dioxins and furans is unclear given the recent extensive remedial activities at this site. The congener patterns in the sediment and mussel sample were consistent with samples from 1993 before remedial activities suggesting a common source. NYSDEC is presently investigating possible sources and the extent of contamination in the cove. The high concentrations in mussel tissue showed that these compounds were still bioavailable in this cove. Fish, other aquatic biota and waterfowl move freely in and out of the cove to feed and sediment is transported from the cove to the Little Niagara River. All these factors suggest that dioxins and furans in this cove were bioavailable to the Niagara River.

Concentrations of 2,3,7,8 T4CDD in sediment from the Pettit Flume site were 350 pg/g. The TEQ for the Pettit Flume cove sediment was 20,073 pg/g. In comparison the TEQ for Fort Erie was 11.3 pg/g and for Bloody Run Creek it was 58,543 pg/g.

Summary of organochlorine pesticides, PCBs, industrial compounds and chlorinated benzene contaminants and PAHs in caged mussel tissue from the 21 day exposure to the Niagara River. Station locations in Fig. 1 and Appendix A & A1.

Canadian Sites	***Contaminant*** ($_{(t)}$ - Trace concentrations, interpret with caution)
Fort Erie at Robertson Street	pp'-DDE$_{(t)}$
Black Creek (mouth)	pp'-DDE$_{(t)}$
Chippawa Channel	pp'-DDE$_{(t)}$
Niagara-on-the-Lake	
US Sites	***Contaminant*** ($_{(t)}$ - Trace concentrations, interpret with caution)
Buffalo River	pp'-DDE$_{(t)}$, chrysene$_{(t)}$, pyrene$_{(t)}$
Tonawanda Channel (upstream of Two Mile Ck)	PCBs, acenaphthene$_{(t)}$

Two Mile Creek (mouth)	pp'-DDE$_{(t)}$, PCBs, HCB$_{(t)}$, octachlorostyrene$_{(t)}$. benzo(a)anthracene$_{(t)}$, chrysene, benzo(b)fluoranthene$_{(t)}$, fluoranthene, phenanthrene$_{(t)}$, pyrene
Pettit Flume (upstream)	pp'-DDE$_{(t)}$, PCBs$_{(t)}$
Pettit Flume (site B)	pp'-DDE$_{(t)}$, PCBs$_{(t)}$, pentachlorobenzene, 1,2,3,4-tetrachlorobenzene$_{(t)}$, 1,2,3,5-tetrachlorobenzene$_{(t)}$, HCB, 1,2,4,5-tetrachlorobenzene$_{(t)}$, 1,2,3-trichlorobenzene$_{(t)}$, 1,3,5-trichlorobenzene$_{(t)}$, 2,4,5-trichlorotoluene$_{(t)}$ chrysene, pyrene benzo(a)anthracene$_{(t)}$, fluoranthene, phenanthrene$_{(t)}$, benzo(g,h,i)perylene$_{(t)}$, indeno(1,2,3-cd)pyrene$_{(t)}$
Gratwick/Riverside Park (upstream)	PCBs$_{(t)}$
Gratwick/Riverside Park	pp'-DDE$_{(t)}$, PCBs$_{(t)}$, HCB $_{(t)}$, octachlorostyrene
102nd Street Landfill (upstream)	pp'-DDE$_{(t)}$, PCBs$_{(t)}$
102nd Street Landfill	PCBs$_{(t)}$, pp'-DDE$_{(t)}$, HCB $_{(t)}$, octachlorostyrene$_{(t)}$
Cayuga Creek	a-BHC$_{(t)}$, b-BHC$_{(t)}$, pp'-DDE$_{(t)}$, PCBs, HCB$_{(t)}$, octachlorostyrene$_{(t)}$, pentachlorobenzene$_{(t)}$
Upstream (Occidental) Sewer A	PCBs$_{(t)}$, pp'-DDE$_{(t)}$
(Occidental) Sewer A	PCBs$_{(t)}$
(Occidental) Sewer B	PCBs$_{(t)}$, hexachlorobutadiene$_{(t)}$, HCB$_{(t)}$, hexachloroethane$_{(t)}$, pentachlorobenzene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$ 2,4,5-trichlorotoluene$_{(t)}$,
(Occidental) - between Sewer B and Sewer C	PCBs$_{(t)}$, pp'-DDT$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$,
(Occidental) Sewer C	PCBs$_{(t)}$, pp'-DDE$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene$_{(t)}$,2,4,5-trichlorotoluene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$, 1,2,4 -trichlorobenzene$_{(t)}$
(Occidental) - (between Sewer C and Sewer 003)	PCBs$_{(t)}$, hexachlorobutadiene$_{(t)}$, HCB$_{(t)}$, hexachloroethane$_{(t)}$, pentachlorobenzene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$,
Occidental Sewer 003	a-BHC$_{(t)}$, b-BHC$_{(t)}$, pp'-DDE$_{(t)}$, PCBs$_{(t)}$, mirex$_{(t)}$, hexachlorobutadiene, HCB, hexachloroethane$_{(t)}$, octachlorostyrene, pentachlorobenzene, 2,3,6-trichlorotoluene$_{(t)}$, 2,4,5-trichlorotoluene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$, 1,2,4.5-tetrachlorobenzene
Occidental - Storm Sewer	pp'-DDE$_{(t)}$, PCBs$_{(t)}$, mirex$_{(t)}$, hexachlorobutadiene$_{(t)}$ HCB, hexachloroethane$_{(t)}$, octachlorostyrene$_{(t)}$, pentachlorobenzene$_{(t)}$, 2,3,6-trichlorotoluene$_{(t)}$, 1,2,3,4-tetrachlorobenzene$_{(t)}$, 1,2,4,5-tetrachlorobenzene$_{(t)}$
Gill Creek (mouth)	pp'-DDE$_{(t)}$, PCBs$_{(t)}$, a-BHC$_{(t)}$, b-BHC$_{(t)}$, HCB$_{(t)}$, hexachloroethane$_{(t)}$, hexachlorobutadiene, pentachlorobenzene$_{(t)}$, 1,2,4,5-tetrachlorobenzene$_{(t)}$, 1,3,5-trichlorobenzene$_{(t)}$
Bloody Run Creek (upstream)	pp'-DDE$_{(t)}$, PCBs$_{(t)}$
Bloody Run Creek	pp'-DDE$_{(t)}$, PCBs$_{(t)}$, hexachlorobutadiene, HCB, pentachlorobenzene, 2,3,6-trichlorotoluene, 1,2,3,4-tetrachlorobenzene$_{(t)}$, 1,2,3,5-tetrachlorobenzene$_{(t)}$

Long Term Deployment of Caged Mussels - Summary of Findings.

Mussels were deployed up to 127 days at Gratwick Riverside Park, the 102nd Street Landfill site, in Cayuga Creek and at the mouth of Two Mile Creek. Mussels were analysed for all parameters at these sites with the exception of Two Mile Creek where mussels were only analysed for total PCBs.

Mussels deployed at the 102nd Street Landfill, Cayuga Creek and Gratwick Riverside Park accumulated hexachlorobenzene and pp'-DDE at concentrations close to the detection limit. Trace concentrations of pentachlorobenzene and α-BHC and β-BHC were only detected in mussels deployed at Cayuga Creek.

PCBs were detected in mussels deployed at all four sites. Results were only available for up to 28 days of deployment at Two-Mile Creek. PCBs were bioaccumulated after one day of deployment and concentrations continued to increase throughout the 28 days (final concentrations ranged from 140 to 160 ng/g). Results from a two-way ANOVA using log-transformed PCB tissue concentrations in mussels deployed at the three remaining sites suggest that PCB concentrations varied with time but the relationships differed among the sites. The two factors in the ANOVA were day and site. The statistically significant ($p<0.001$) interaction between the two factors suggest that the rate of PCB uptake differed among the sites over time. Final mean PCB concentrations at 102nd Street, Gratwick Riverside Park and Cayuga Creek were 100 ng/g (standard deviation (SD) 40 ng/g), 73 ng/g (SD 11.5 ng/g) and 173 ng/g (SD 30.5 ng/g) respectively.

The general pattern of bioaccumulation was more representative of a continuous low level source than short term contaminant pulses entering the aquatic environment. It was also characteristic of a parameter with a high octanol-water partition coefficient (log K_{ow}) such as PCBs (Oliver 1987; Hawker and Connell 1985). For 102nd Street and Gratwick Riverside Park mussel concentrations reached equilibrium from14 to 28 days of exposure. However, although PCB concentrations in mussels deployed at Cayuga Creek at 14 days were similar to concentrations at 56 days, concentrations increased again at 98 and 127 days. Similarly, PCB concentrations in mussels at Two Mile Creek did not appear to reach equilibrium by 28 days. These results suggests that the 21 day exposure survey may be insufficient to assess maximum bioaccumulation of PCBs at some stations (Kauss and Angelow 1988; Richman 1997).

Results from the four month survey at Gratwick Riverside Park, the data from previous 21 day deployment surveys at this site, as well as a comparison of data from this site with an upstream reference site suggest that the mussel monitoring station for this hazardous waste site may not be effectively monitoring the release of contaminants to the river and should be relocated.

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INTRODUCTION

The Niagara River has been contaminated due to the discharge of persistent bioaccumulative and toxic chemicals from outfalls and hazardous waste landfills (Elder *et al.* 1981; Kuntz and Warry 1983; Jaffe and Hites 1984; NRTC 1984; Gradient Corp./Geotrans Inc. 1988; Monenco 1991; Raven 1991).The contaminants that were historically discharged, and which (in some cases), are still released from outfalls and inactive hazardous waste sites include chemicals such as mirex, PCBs (polychlorinated biphenyls), organochlorine pesticides such as BHC (lindane) and chlordane, chlorinated benzenes, chlorinated phenols, polycyclic aromatic hydrocarbons (PAH), and polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (Interagency Task Force on Hazardous Waste 1979; Elder *et al.* 1981; Jaffe and Hites 1984; NRTC 1984; US EPA and NYSDEC 1998, Niagara River Data Interpretation Group, 1996). The integrity of the aquatic ecosystem and fish and wildlife habitat throughout the Niagara River and Lake Ontario has been impaired by contaminants entering the system.

Since 1980 the Ontario Ministry of Environment (MOE) has been committed to routine and specialized biomonitoring of contaminants in the Niagara River using caged mussels (*Elliptio complanata*) in addition to other long term monitoring programs (spottail shiner contaminant monitoring and the sport fish contaminant monitoring program), as part of Ontario's commitment to the Niagara River Toxic Management Plan. This plan was part of a binational agreement (first signed in 1987), to improve the environmental quality of the Niagara River. The cooperative assistance of the New York State Department of Environmental Conservation (NYSDEC) has enabled the MOE to deploy mussels on the American as well as the Canadian side of the river. These studies have provided information on suspected contaminant sources and source areas and the effectiveness of site remediation in reducing contaminants in the river between Fort Erie and Niagara-on-the-Lake (Kauss 1987; Kauss and Angelow 1988; Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997).

Biomonitors are an effective means of detecting bioaccumulative contaminants in the water when ambient concentrations are too low to be measured directly using conventional water sampling and analytical methods. The principle behind the mussel biomonitoring program is to take organisms from an uncontaminated site and place them in an environment that is known or suspected of being contaminated with persistent bioaccumulative substances. The biomonitors are left for a specified time to accumulate contaminants and are then analysed to determine the contaminant concentrations in their tissue. By strategically locating the organisms upstream and downstream from a source, the presence or absence of the contaminants in the water body can be determined. The detection of the contaminants in the mussels indicates that these contaminants are bioavailable in the aquatic environment. The absence of a contaminant in the mussel tissue is less definitive. It may suggest that the contaminant is not present or it is not bioavailable in the surrounding environment. However, because of the sight specific nature of this biomonitor it may also mean that the mussels were not placed near enough to the source to adequately detect the presence of the contaminants.

The freshwater mussel, *Elliptio complanata*, is a filter feeder feeding on plankton and organic detritus and will, therefore, accumulate contaminants directly from the water column and from particulate matter (Pennak 1978). This method of feeding renders the mussel a good biomonitor since contaminants tend to partition between the dissolved phase and the solid phase where they become associated with sediment or suspended particulates through adsorptive processes. Mussels are abundant and easily collected and transported. They are sedentary organisms and responsive to their environment. Mussels can integrate short term fluctuations in contaminant levels and, accordingly, tissue concentrations reflect short term contaminant pulses which may not be detected by routine water quality monitoring (Muncaster *et al.* 1989; Metcalfe and Charlton 1990; Kauss and Hamdy 1991; Lobel *et al.* 1991). Conversely, because the sampling design is limited to a particular deployment period, results only reflect the exposure during that period. The results obtained at any one sampling event represent the current contamination integrated by that specific organism and cannot be extrapolated to yearly loadings from sources. Likewise, significant contaminant inputs could be missed if they occur outside the designated period of biomonitoring.

Objectives

The general objective of the mussel biomonitoring program is to monitor the distribution of contaminants in the Niagara River and identify areas of concern for point and non point source investigations.

More specific objectives of this survey were to investigate:

- *how tissue contaminant concentrations of caged mussels deployed in the Niagara River for 21 days varied spatially between the stations?*
- *the qualitative temporal patterns associated with the presence/absence of contaminants (i.e. are specific contaminants consistently detected at specific locations over time?).*
- *the variability in contaminant uptake patterns in caged mussels deployed at four stations over a long term (4 month) exposure.*

This report presents the results of the 1997 mussel biomonitoring survey.

METHODS

Field Sampling and Station Locations

Caged Mussels

In 1997, there were two studies initiated by the MOE; the routine deployment of caged mussels at near shore stations on the Canadian and American sides of the river for 21 days of exposure, and long term deployments for up to four months at four stations. The long term deployment survey was a follow up to a similar survey in 1995 at two stations (Richman 1997).

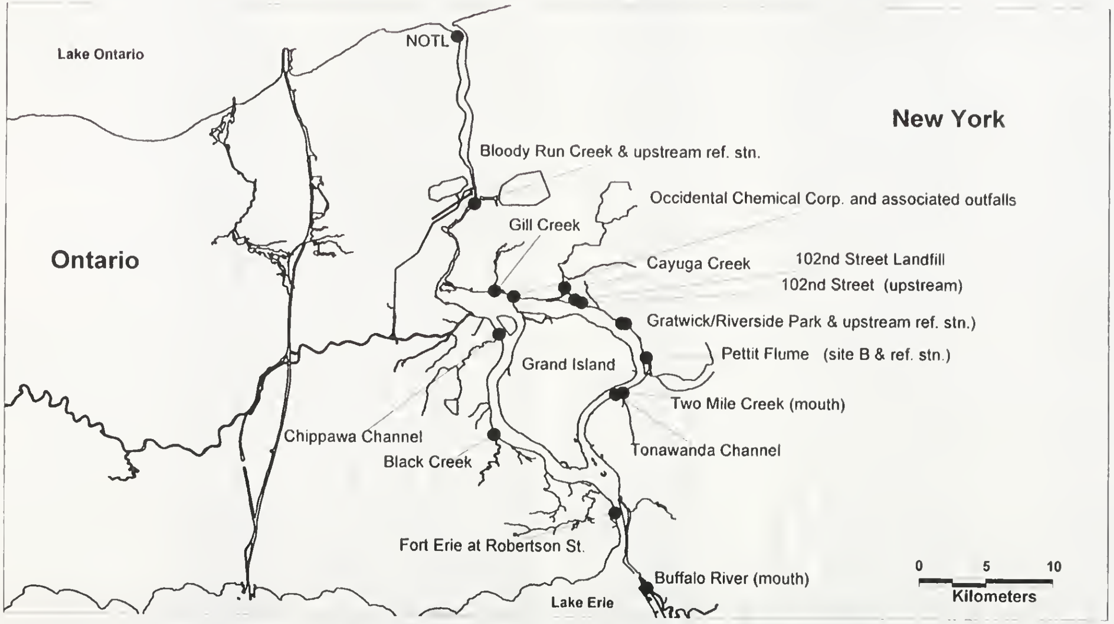
The mussels used for the study originated from Balsam Lake (a relatively uncontaminated lake located in Victoria County, Ontario). Only mussels between 6.5 and 7.2 cm were collected to reduce variability due to tissue weight and mussel age. The mussels were collected by divers and placed in buckets lined with clean bioassay (food-grade) polyethylene bags partially filled with lake water for transportation. The bags were sealed with air trapped inside and rapid temperature fluctuations were avoided. Three random replicate samples of these mussels were submitted for tissue analysis to determine initial concentrations of contaminants. These mussels are referred to as the Balsam Lake control mussels in this report.

Mussels were placed in the Niagara River at 32 sampling stations during the week of July 14, 1997 and retrieved after three weeks of exposure during the week of August 3, 1997 (Appendix A for GPS positions). Retrieval of caged mussels for the three week survey was successful at 25 stations (Figure 1 & Appendix A1). The remaining seven stations were either vandalized or the cages were lost.

At each station at least six mussels were placed in 30 x 45 cm envelope-shaped cages constructed of 1.25 cm galvanized mesh poultry netting. A nylon rope was attached to the cages and then anchored to the river bottom with a cement block. Cages were also anchored to the bottom using pegs or rocks and sometimes attached to a shoreline structure. The mussels were immediately shucked after retrieval, excess water was drained and the soft tissues were weighed, individually wrapped in hexane-rinsed aluminum foil, and placed in plastic bags. Three replicate samples were analysed for contaminants at each station.

Sampling stations were located at the mouth of tributaries, in the Tonawanda Channel, Chippawa Channel and near known industries and hazardous waste sites. The cages were usually placed within two to three metres from shore because the study was designed to investigate the impact of shore based sources on water quality rather than ambient river conditions.

Figure 1: Station Location for Niagara River Mussel Biomonitoring Survey, 1997.



Mussels were retrieved from four stations on the Canadian side of the river and 21 stations on the U.S. side. Most of the sampling sites have been monitored in previous MOE surveys. New stations included an upstream control for Gratwick Riverside Park and several sewers associated with the Occidental Chemical Corporation Buffalo Avenue plant. Mussel were deployed at all the outfalls in front of the Occidental property in an attempt to clarify the source of the contaminants along the waterfront in the area associated with the Occidental plant and waste sites. The stations upstream of Sewer 003 have been identified as Sewer A, B and C with the outfall farthest upstream identified as Sewer A (figure provided in Appendix A1).

At four stations (102nd Street Landfill, Cayuga Creek, Gratwick Riverside Park and Two Mile Creek) a sufficient number of mussels were deployed in cages for long term exposure experiments. Mussels were retrieved after 1 day, 2 days, 3 days and 7,14, 21, 28, 56, 98 and 127 days of exposure. Contaminant data were available for the entire sampling period for the Gratwick Riverside Park and Cayuga Creek site; however, data were only available up to 98 days of exposure from the 102nd Street site and only up to 28 days from the Two Mile Creek site. Mussels were analysed for all parameters at these sites with the exception of Two Mile Creek where mussels were only analysed for total PCBs.

Sediment

Single surface sediment samples were collected from four stations for analysis of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, particle size and TOC. Surface samples (top 3 cm) were collected using a stainless steel spatula and placed in sample jars. Samples were kept on ice in the field, and refrigerated at 4°C in the dark until analysis. The general sample composition (e.g. sand, silt etc.), sediment colour, any unusual features were recorded.

Analytical Methods

All mussel and sediment samples were submitted for chemical analysis at the MOE laboratory in Etobicoke, Ontario. Mussels were analysed for the following parameters: organochlorine pesticides, total PCB's and chlorinated benzenes (Table 1). Caged mussels and sediment were collected from four of the stations for analysis of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans and mussels were collected from nine stations for analysis of PAHs. All results were reported on a wet weight basis. Results for sediment were reported on a dry weight basis.

All laboratory analytical procedures for contaminants in mussels and sediment and for particle size analysis in sediment followed the methodology outlined in the Handbook of Analytical Methods for Environmental Samples (OMOE 1983). Procedural updates for biomaterial and sediment analysis were provided in OMOE 1995 a&b and OMOE 1997a to 1997d.

TABLE 1: Mussel tissue was submitted for the following analyses.

All samples were sumbitted for the following analyses:		Samples from four stations were submitted for:	Samples from nine stations were submitted for:
PCBs (total)	1,3,5-trichlorobenzene	Polychlorinated dibenzo-p-dioxins	Naphthalene
Heptachlor	1,2,4-trichlorobenzene	Polychlorinated dibenzofurans	Acenaphthylene
Aldrin	1,2,3-trichlorobenzene		Acenaphthene
Photomirex	1,2,4,5-tetrachlorobenzene		Fluorene
Mirex	1,2,3,4-tetrachlorobenzene		Phenanthrene
α–BHC	1,2,3,5-tetrachlorobenzene		Anthracene
β–BHC	Pentachlorobenzene		Fluoranthene
γ–BHC	Hexachlorobenzene		Pyrene
α–chlordane	2,4,5-trichlorotoluene		Benzo(a)anthracene
γ–chlordane	2,3,6-trichlorotoluene		Chrysene
pp-DDE	2,6-dichlorobenzyl chloride		Benzo(b)fluoranthene
op-DDT			Benzo(b/k)fluoranthene
pp-DDD			Benzo(a)pyrene
pp-DDT			Benzo(g,h,i)perylene
Octachlorostyrene			Dibenzo(a,h)anthracene
Toxaphene			Indeno(1,2,3-c,d)pyrene
Hexachloroethane			
Hexachlorobutadiene			

Data Analysis

The range in contaminant concentrations in mussels was provided for replicate samples for each parameter at each station in tables summarized within the report. Means and standard deviations were provided if all replicates had concentrations above the analytical detection limit. Concentrations described as "trace" should be interpreted with caution. These values represent "a measurable trace amount". All "raw data" are presented in Appendix D. Values at "trace" concentrations are noted by a "t" in the Appendix.

Mean contaminant concentrations in mussels were compared among stations with a one way analysis of variance (ANOVA) using the SAS statistical package (SAS Institute Inc. 1988). The Tukey's Studentized Range Test was applied to test station differences. The analysis was performed on non-transformed data using stations where mussel tissue concentrations were all above the detection limit for the compound of interest. The contaminants in the ANOVA included total PCBs, hexachlorobenzene, pentachlorobenzene and 1,2,3,4-tetrachlorobenzene.

A two way ANOVA was performed on log transformed mussel tissue data for total PCBs for the long term deployment survey to determine the significance of site and time with respect to tissue concentrations. The ANOVA was based on the assumption that both station and time were non-random. The ANOVA was performed using Microsoft Excel Analysis ToolPak.

RESULTS AND DISCUSSION

Organochlorine Pesticides and PCBs

Organochlorine pesticides and PCBs were not detected in the Balsam Lake control mussels.

Mussels placed at four stations on the Canadian side of the river only accumulated trace concentrations of p,p'-DDE (metabolite of the pesticide DDT). Trace concentrations p,p'-DDE were also detected at almost all stations on the American side of the river. The presence of p,p'-DDE in the mussels was likely due to the historic use of DDT in the Lake Erie and Niagara River watersheds (Table 2). Concentrations of p,p'-DDE in mussel tissues in 1997 were similar to concentrations detected in previous years of sampling (Kauss and Angelow 1988; Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997).

Trace concentrations of α-BHC and β-BHC (hexachlorocyclohexane) were detected in mussels at three sites on the American side of the river; Occidental Chemical Corporation's sewer 003 (Buffalo Avenue plant) (herein referred to as Occidental sewer 003), the mouth

TABLE 2: Range in concentrations (ng/g wet weight) of organochlorine pesticides and PCBs in mussels introduced to the Niagara River for thre weeks, 1997. If all replicate samples were above the detection limit the mean and standard deviation was also provided.

Sampling Station	Station	α-BHC	mean	β-BHC	mean	Mirex	mean	Total PCBs	mean	pp'-DDT	pp'-DDE	mean
Detection Limit	number	1	(SD)	1	(SD)	5	(SD)	20	(SD)	5	1	(SD)
Canadian Sites												
Fort Erie at Robertson St.	(5-2)-203					.		.		.	3-4	3
												(0 6)
Black Creek (mouth)	(5-2)-191					.				.	( )-2	
Chippawa Channel	(5-2)-51					.				.	2	2
												(0)
NOTL	(11-2)-9			.		.		.		.	.	
US Sites												
Buffalo River	(5-2)-196	.		.		.		.			2-3	2
												(0 6)
Tonawanda Channel (upstream of Two Mile Creek)	(5-2)-92							20-100	53	.		
									(41 6)			
Two Mile Creek (mouth)	(5-2)-197	.		.		.		80-100	93	.	3-4	4
									(11 5)			(0 6)
Pettit Flume (upstream)	(5-2)-185	.		.		.		20	20	.	(.)-3	
									(0)			
Pettit Flume (site B)	(5-2)-186	.				.		(.)-40		.	(.)-5	
Gratwick/Riverside Park (upstream)	(5-2)-31	.		.		.		20-40	27	.	.	
									(11 5)			
Gratwick/Riverside Park	(5-2)-199	.			.	.		40	40	.	( )-3	
									(0)			
102nd Street (upstream)	(5-2)-93			.		.		( )-20		.	( )-2	
102nd Street	(5-2)-22							20-40	27	.	(.)-2	
									(11.5)			
Cayuga Creek	(5-15)-31	5-8	6	5-8	6	.		40-60	53	.	3-4	4
			(1.5)		(1.5)				(11.5)			(0 6)
Upstream Sewer A	(5-2)-47	.						20-40	27	.	( )-6	
									(11 5)			
Sewer A	(5-2)-46	.		.		.		20-40	27	.	.	
									(11.5)			
Sewer B	(5-2)-94	.		.		.		(.)-20		.	.	
Between Sewer B and Sewer C	(5-2)-45	.		.		.		20-40	33	( )-15	.	
									(11 6)			
Sewer C	(5-2)-44	.				.		40	40	.	(.)-5	
									(0)			
Between Sewer C and Sewer 003	(5-2)-43	.		.		.		40	40	.	.	
									(0)			
Occidental Sewer 003	(5-2)-42	( )-6		( )-2		20	20	60-80	67	.	( )-8	
							(0)		(11 5)			
Storm Sewer - S&N	(5-2)-40	.		.		10-15	12	40-60	47	.	3-5	4
							(2 9)		(11 5)			(1 2)
Gill Creek	(5-2)-37	2-4	3	(.)-2		.		60	60	.	(.)-4	
			(1)						(0)			
Bloody Run Creek (upstream)	(11-2)-18	.		.		.		(.)-40		.	(.)-2	
Bloody Run Creek (mouth)	(11-2)-17	.		.		.		20-40	33	.	3-5	4
									(11 5)			(1)
Balsam Lake Control Mussels	(18-1)-1					.		.				

"." Compound was below the detection limit

Aldrin, Heptachlor, Toxaphene, Photomirex, γ-BHC, α-chlordane, γ-chlordane, p'p-DDD, o'p-DDT and 2,6-dichlorobenzyl chloride were not detected in any samples analysed of Gill Creek and at a station in Cayuga Creek. These compounds have been detected at similar concentrations in mussels deployed at these stations in previous surveys (Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997). The absence of these compounds in mussels deployed at the 102nd Street waste site is noteworthy. Detectable concentrations of α-BHC, β-BHC and γ-BHC have routinely been present in mussels deployed at this site prior to the remedial activities. Site remediation and the removal of contaminated sediment from the river has likely reduced the presence and bioavailability of contaminants to the river.

Mirex was detected at trace concentrations in mussels deployed at Occidental sewer 003 (mean 20 ng/g, standard deviation (SD) 0) and at the mouth of a storm sewer which receives runoff from the surrounding property located 66 m downstream of sewer 003 (mean 12 ng/g SD 2.9 ng/g). Mirex has been associated sporadically with all the outfalls at trace concentrations since 1983 when caged mussel monitoring was initiated at these sites. The highest concentrations were detected at sewer 003 in 1987 (mean 167 ng/g - SD (standard deviation) 59.7 ng/g). Subsequently only trace concentrations were present in deployed mussels. Mirex was rarely detected at other sites along the river. Occidental Chemical Corporation (formerly Hooker Chemical and Plastics Corporation) was the sole producer of mirex in 1959 (Interagency Task Force on Hazardous Waste 1979). Since the use of mirex was limited in 1976 by Canadian and U.S. legislation its presence in mussels deployed at these sites suggests that residues from previous operations at the facility are still leaching into the river.

Trace concentrations of PCBs were present in mussels deployed at all stations on the American side of the river (Table 2). Generally concentrations among all stations were similar making it difficult to identify specific point or non-point sources along the Tonawanda Channel and in the lower Niagara River. In contrast, PCBs were not detected in mussels deployed on the Canadian side of the river. The highest mean concentration of PCBs for the three week survey were present in mussels deployed in the mouth of Two Mile Creek (mean 93 ng/g, SD 11.5 ng/g) and at Occidental sewer 003 (mean 67 ng/g, SD 11.5 ng/g). A one way ANOVA (excluding stations with concentrations below the detection limit) and Tukey's Studentized Range Test showed that PCB concentrations in mussels from Two Mile Creek were not significantly different than PCB concentrations in mussels deployed at Occidental Sewer 003, the mouth of Gill Creek, Cayuga Creek and at the Tonawanda Channel station but concentrations were significantly higher ($p<0.05$) than the remaining stations.

High concentrations of PCBs have been detected at Two Mile Creek in previous surveys since 1987 with the exception of the 1995 survey (Richman 1997). The 1997 results confirm the results from earlier surveys. Tissue concentrations in 1987 ranged from below the detection limit to 239 ng/g, in 1991 the mean concentration was 108 ng/g (SD 32 ng/g) and in 1993 the mean concentration was 129 ng/g (SD 15.7 ng/g). The four month deployment study at Two Mile Creek showed mussel tissue concentrations of PCBs gradually increasing over time with concentrations as high as 160 ng/g after 28 days of deployment (Table 6). These results suggest that the creek should be investigated as a potential source of PCBs to the Niagara River. Unfortunately the site was vandalized after 28 days and additional data were not available.

Results from the four month deployment study show PCB concentrations as high as 200 ng/g in mussels deployed at Cayuga Creek after 127 days of exposure (Table 6). The mean concentrations after three weeks of exposure was 53 ng/g (SD 11.5 ng/g).This concentration was consistent with results from the 1995 three week deployment survey (range was from below the detection limit to 120 ng/g) which was the first time this site was monitored. In general, the four month survey results suggest that a deployment time that is longer than the routine 21 days may be required for mussels to bioaccumulate contaminants such as PCBs to a maximum tissue concentration.

A major clean up of PCB contaminated sediment upstream of the mouth of Gill Creek was completed in 1991. Gill Creek was historically a known PCB "hot spot" (Interagency Task Force on Hazardous Waste 1979; Raven 1991) and a significant source of PCBs to the Niagara River and subsequently Lake Ontario. Prior to remediation high concentrations of PCBs were detected in mussels deployed in the Niagara River downstream of the creek mouth. Mean concentrations were as high as 935 ng/g (SD 163 ng/g) in 1987 and 2,623 ng/g (SD 745 ng/g) in 1991. Mean PCB concentrations in mussels deployed at this site in 1993 were 81 ng/g (SD 19 ng/g) after the site was remediated (Richman 1994). In 1997 PCB concentrations were similar to1993 and consistent with concentrations detected at all sites (upstream and downstream) along the American side of the Niagara River (mean 60 ng/g, SD 0).

Another site in Gill Creek north of highway 384 (upstream of the area previously remediated for PCBs), typically had high concentrations of PCBs in mussels in previous surveys suggesting additional source(s) of PCBs to this area. Unfortunately, although this site was included in the survey in 1997 we were unable to retrieve the cages because of deep mud in the creek bed. Contamination of this site with PCBs has been confirmed by NYSDEC.

Chlorinated Benzenes and Industrial Compounds

Chlorinated benzenes were not detected in any mussels deployed on the Canadian side of the river or in the Balsam Lake control mussels.

The most frequently detected chlorinated benzenes on the American side of the river in mussel tissue were hexachlorobenzene, pentachlorobenzene and 1,2,3,4-tetrachlorobenzene (Table 3). Trichlorobenzene concentrations were low and only detected at a few stations. Occidental Sewer 003 had significantly higher ($p<0.05$) concentrations of hexachlorobenzene and 1,2,3,4-tetrachlorobenzene than other stations in the survey although concentrations were similar to those found in mussels deployed at the Pettit Flume inlet cove. Mussels deployed at the Pettit Flume, Occidental Sewer 003 and Bloody

TABLE 3: Range in concentrations (ng/g wet weight) of chlorinated benzenes and chlorinated industrial compounds in mussels introduced to the Niagara River for three weeks, 1997. If all replicate samples were above the detection limit the mean and standard deviation was also provided.

Sampling Station	Station number	Hexa-chlorobutadien	mean	Hexa-chlorobenzen	mean	Hexa-chloroethane	mean	Octa-chlorostyrene	mean	Penta-chlorobenzen	mean	2,3,6-Trichlorotoluen	mean	2,4,5-Trichlorotoluen	mean
Detection Limit		1	(SD)	1	(SD)	1	(SD)	1	(SD)	1	(SD)	1	(SD)	1	(SD)
Canadian Sites															
Fort Erie at Robertson St.	(5-2)-203	.		.		.		.		.		.		.	
Black Creek (mouth)	(5-2)-191	.		.		.		.		.		.		.	
Chippawa Channel	(5-2)-51	.		.		.		.		.		.		.	
NOTL	(11-2)-9	.		.		.		.		.		.		.	
US Sites															
Buffalo River	(5-2)-196	.		.		.		.		.		.		.	
Tonawanda Channel (upstream of Two Mile Creek)	(5-2)-92	.		.		.		.		.		.		.	
Two Mile Creek (mouth)	(5-2)-197	.		2	2 (0)	.		(.)-4		.		.		.	
Pettit Flume (upstream)	(5-2)-185	.		.		.		.		.		.		.	
Pettit Flume (site B)	(5-2)-186	.		10-24	17 (7)	.		.		12-13	13 (0.6)	.		(.)-3	
Gratwick/Riverside Park (upstream)	(5-2)-31	.		.		.		.		.		.		.	
Gratwick/Riverside Park	(5-2)-199	.		.		.		2	2 (0)	.		.		.	
102nd Street (upstream)	(5-2)-93	.		.		.		.		.		.		.	
102nd Street	(5-2)-22	.		.		.		(.)-2		.		.		.	
Cayuga Creek	(5-15)-31	.		2-3	2 (0.6)	.		(.)-2		2	2 (0)	.		.	
Upstream Sewer A	(5-2)-47	.		.		.		.		.		.		.	
Sewer A	(5-2)-46	.		.		.		.		.		.		.	
Sewer B	(5-2)-94	2	2 (0)	(.)-2		(.)-2		.		2-3	2 (0.6)	.		(.)-2	
Between Sewer B and Sewer C	(5-2)-45	.		( )-2		.		.		(.)-3		.		.	
Sewer C	(5-2)-44	.		2-3	3 (0.6)	.		.		2-4	3 (1.0)	.		(.)-2	
Between Sewer C and Sewer 003	(5-2)-43	2	2 (0)	2-3	2 (0.6)	(.)-2		.		3	3 (0)	.		.	
Occidental Sewer 003	(5-2)-42	9-11	10 (1.2)	21-32	27 (5.5)	(.)-2		20-23	21 (1.7)	9-12	10 (1.5)	3-5	4 (1.0)	3-7	5 (2.1)
Storm Sewer - S&N	(5-2)-40	5-6	6 (0.6)	9-13	10 (2.3)	(.)-2		3-6	4 (1.7)	4-7	5 (1.7)	(.)-2		.	
Gill Creek	(5-2)-37	120-160	147 (23.1)	3	3 (0)	2-8	4 (3.5)	.		2	2 (0)	.		.	
Bloody Run Creek (upstream)	(11-2)-18	.		.		.		.		.		.		.	
Bloody Run Creek (mouth)	(11-2)-17	3	3 (0)	11-13	12 (1.2)	.		.		7-10	8 (1.5)	3-4	3 (0.6)	.	
Balsam Lake Control Mussels	(18-1)-1														

Table 3 continued:

Sampling Station	Station number	1,2,3-Trichlorobonzene	mean	1,2,3,4-Tetrachlorobenzene	mean	1,2,3,5-Tetrachlorobenzene	mean	1,2,4-Trichlorobenzene	mean	1,2,4,5-Tetrachlorobenzene	mean	1,3,5-Trichlorobenzene	mean
Delection Limit		2	(SD)	1	(SD)	1	(SD)	2	(SD)	1	(SD)	2	(SD)
Canadian Sites													
Fort Erie at Robertson St.	(5-2)-203	.		.		.		.		.		.	
Black Creek (mouth)	(5-2)-191	.		.		.		.		.		.	
Chippawa Channel	(5-2)-51	.		.		.		.		.		.	
NOTL	(11-2)-9	.		.		.		.		.		.	
US Sites													
Buffalo River	(5-2)-196	.		.		.		.		.		.	
Tonawanda Channel (upstream of Two Mile Creek)	(5-2)-92	.		.		.		.		.		.	
Two Mile Creek (mouth)	(5-2)-197	.		.		.		.		.		.	
Pettit Flume (upstream)	(5-2)-185	.		.		.		.		.		.	
Pettit Flume (site B)	(5-2)-186	(.)-4		5-7	6	3	3	.		4	4	4	4
					(1.0)		(0)				(0)		(0)
Gratwick/Riverside Park (upstream)	(5-2)-31	.		.		.		.		.		.	
Gratwick/Riverside Park	(5-2)-199	.		.		.		.		.		.	
102nd Street (upstream)	(5-2)-93	.		.		.		.		.		.	
102nd Street	(5-2)-22	.		.		.		.		.		.	
Cayuga Creek	(5-15)-31	.		.		.		.		.		.	
Upstream Sewer A	(5-2)-47	.		.		.		.		.		.	
Sewer A	(5-2)-46	.		.		.		.		.		.	
Sewer B	(5-2)-94	.		(.)-2		.		.		.		.	
Between Sewer B and Sewer C	(5-2)-45	.		(.)-2		.		.		.		.	
Sewer C	(5-2)-44	.		(.)-3		.		(.)-14		.		.	
Between Sewer C and Sewer 003	(5-2)-43	.		2	2	.		.		.		.	
					(0)								
Occidental Sewer 003	(5-2)-42	.		8-9	9	.		.		17-29	22	.	
					(0.6)						(6.2)		
Storm Sewer - S&N	(5-2)-40	.		3-5	4	.		.		(.)-9		.	
					(1.0)								
Gill Creek	(5-2)-37	.		.		.		.		(.)-8		10-12	11
													(1.2)
Bloody Run Creek (upstream)	(11-2)-18	.		.		.		.		.		.	
Bloody Run Creek (mouth)	(11-2)-17	.		2-3	3	2-3	2	.		.		.	
					(0.6)		(0.6)						
Balsam Lake Control Mussels	(18-1)-1												

Run Creek had significantly higher ($p<0.05$) concentrations of pentachlorobenzene than mussels deployed at the other stations in the survey.

Trace concentrations of chlorinated benzenes were present in mussels deployed at the sewers associated with the Occidental Chemical Corporation Buffalo Avenue facility. The highest concentrations were in mussels deployed at the mouth of sewer 003 compared with the associated sewers located upstream and downstream (Figure 2 & Appendix A1 for station locations). Most notable were concentrations of 1,2,3,4 tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, hexachlorobenzene, pentachlorobenzene, octachlorostyrene and hexachlorobutadiene. The highest concentrations of octachlorostyrene in the survey were detected at this site (mean 21 ng/g, SD 1.7 ng/g). The presence of these contaminants at this site have been consistent throughout previous MOE mussel surveys (Kauss 1987; Anderson *et al.*1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997).

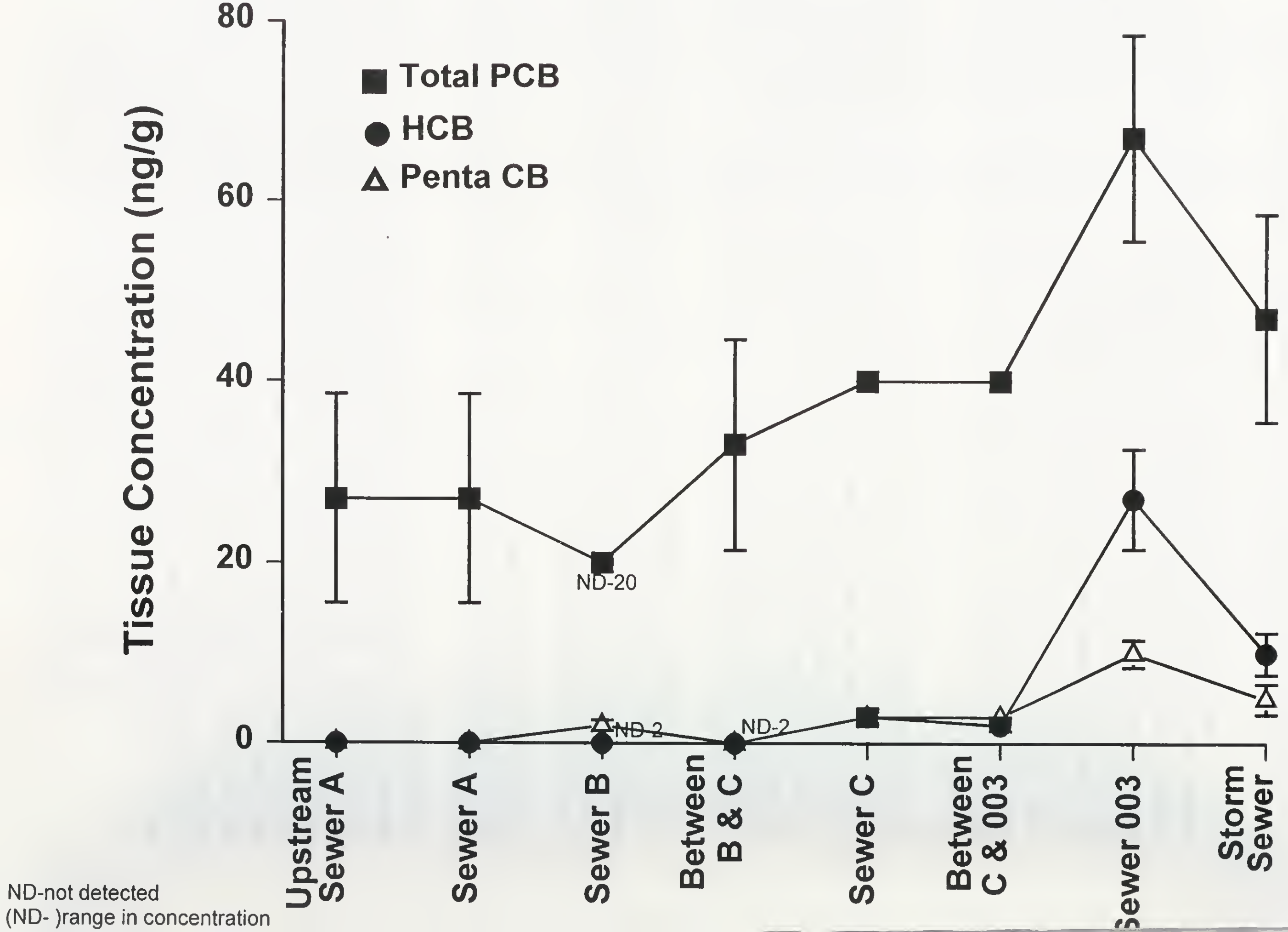
Trace concentrations of 2,3,6- and 2,4,5-trichlorotoluene were detected in mussel tissue from the 003 sewer. Chlorotoluene was a known contaminant in Occidental's effluent (NRTC 1984) and has been consistently detected since 1983 in mussels deployed at the various outfalls associated with the Occidental Chemical Corporation property. In 1997, 2,3,6-trichlorotoluene was also present at trace concentrations in mussels deployed at Bloody Run Creek. It was detected in mussels at Bloody Run Creek in 1989 and 1993 although 2,3,6-trichlorotoluene was not present in mussel tissue in 1995. This compound was not detected at the Bloody Run Creek upstream reference station.

High concentrations of hexachlorobutadiene (range 120 - 160 ng/g) were present in mussels deployed at the mouth of Gill Creek. Lower concentrations (range 2 to 11 ng/g) were accumulated by mussels deployed at sites associated with the Occidental Chemical Corporation and at Bloody Run Creek. Hexachlorobutadiene has been detected at all these sites in previous MOE mussel surveys.

Hexachloroethane was present at trace concentrations at several sites associated with the Occidental facility and at the Gill Creek site. This parameter was not routinely analysed in previous surveys.

The 102nd Street Landfill site was remediated by various containment options and removal of contaminated sediment from the river adjacent to the landfill. Mussels deployed at this site for the 21 day survey had only trace concentrations of octachlorostyrene (range ND - 2 ng/g) (Table 3), and mussels deployed for the four month study accumulated only trace concentrations (range ND-3 ng/g) of hexachlorobenzene (Table 6). Before remediation mussels deployed at the 102nd Street Landfill in the contaminanted sediment have consistently had detectable concentrations of trichlorobenzenes and often the highest concentrations of hexa, penta and tetrachlorinated benzenes relative to other sites monitored in the mussel surveys. For example, in 1995 concentrations of hexachlorobenzene in mussel tissue after a four month deployment ranged from 15 to 74 ng/g. Concentrations of pentachlorobenzene ranged from 110 to 580 ng/g and

Figure 2: Contaminant Concentrations in Mussels Deployed at Stations Associated With the Occidental Chemical Corporation



ND-not detected
(ND-)range in concentration

concentrations of 1,2,3,4-tetrachlorobenzene ranged from 140 to 930 ng/g (Richman 1997). The absence of these contaminants from the mussel tissue in 1997 was noteworthy and was likely due to the removal of the contaminated sediment from the surrounding area and site remediation.

Concentrations of chlorinated benzenes in mussels deployed at the Pettit Flume inlet cove were low relative to previous years of sampling before the remediation of the cove (Anderson *et al.* 1991; Richman 1992; Richman 1993; Richman 1994; Richman 1997). Most notable were mussel tissue concentrations of hexachlorobenzene, pentachlorobenzene and 1,2,3,4 tetrachlorobenzene (which was present at only trace concentrations) (Figure 3). Although the detection of these compounds in deployed mussels suggested that the sewer was still a source of chlorinated benzenes to the cove, the low concentrations showed that the remediation was successful at improving the water quality of the cove. By removing contaminated sediment from the cove an important non point source of contaminants to the Niagara River was eliminated.

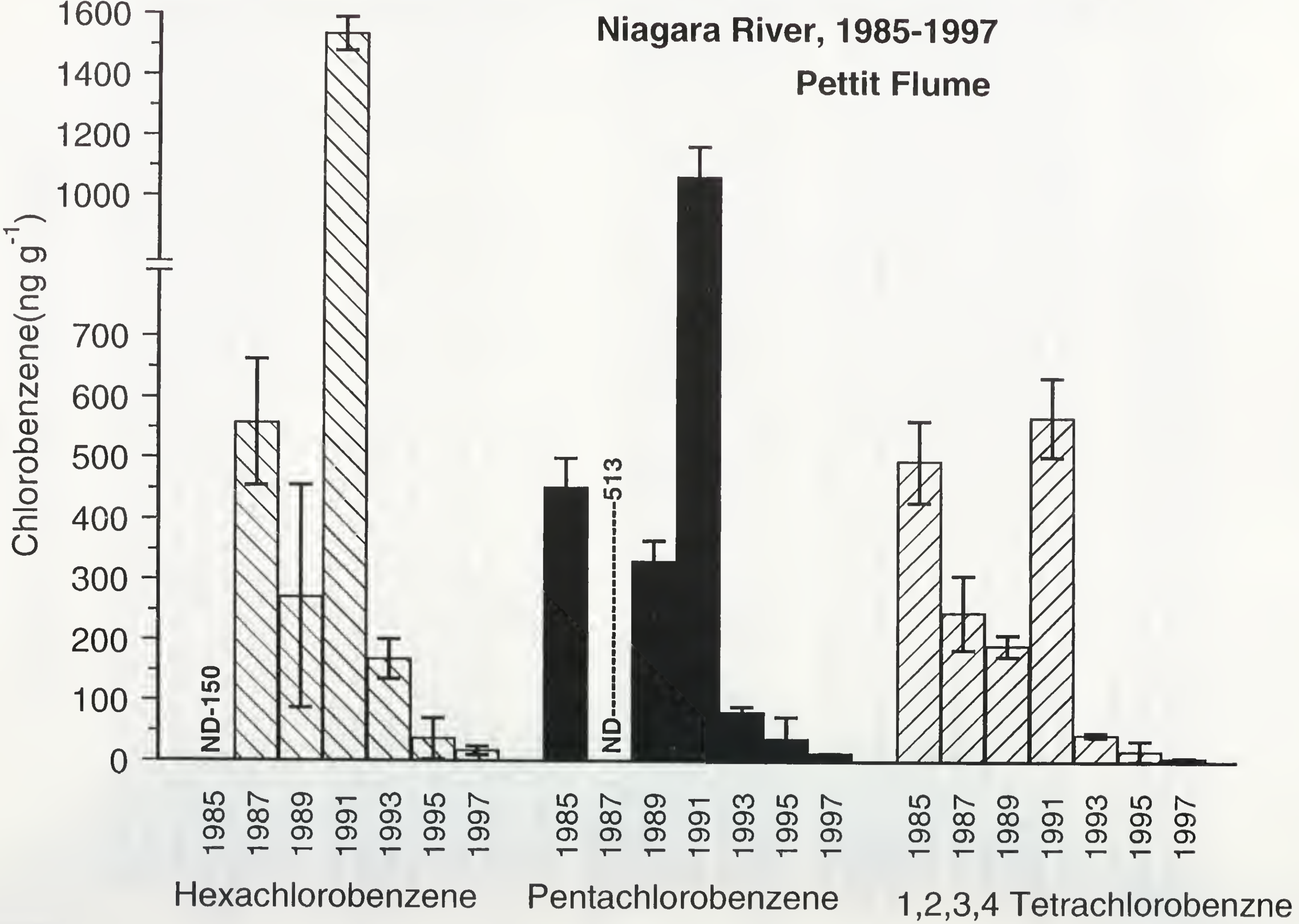
Low and/or trace concentrations of chlorinated benzenes were detected in mussels deployed at the mouth of Bloody Run Creek. Due to the high variability in concentrations consistently detected in mussels deployed at this site through time it is impossible to assess changes in contaminant bioavailability due to remedial efforts at this site. Mussels deployed at a reference station immediately upstream of Bloody Run Creek did not have detectable concentrations of any chlorinated benzenes suggesting that the source of contaminants in mussels at the downstream site was the area surrounding Bloody Run Creek.

Polycyclic Aromatic Hydrocarbons (PAHs)

Mussels were analysed for PAHs at nine stations. PAHs were not detected in the Balsam Lake control mussels or in mussels deployed at three stations on the Canadian side of the river (Fort Erie, Chippawa Channel and Niagara-on-the-Lake), or at two of the six stations on the American side (102nd Street upstream reference station and 102nd Street Landfill site). Only trace concentrations of acenaphthene were detected in mussels at the Tonawanda Channel site and trace concentrations of chrysene and pyrene were detected in mussels at the Buffalo River site (Table 4).

Consistent with previous mussel monitoring surveys, high concentrations of some PAH compounds were detected in mussels deployed at Two-Mile Creek and the Pettit Flume inlet cove suggesting that there were sources of PAHs to these two areas which may in turn act as sources to the Niagara River (Richman 1992; Richman 1994; Richman 1997). Pyrene, phenanthrene, fluoranthene and chrysene have been consistently present in mussels at Two-Mile Creek in past surveys and benzo(a)anthracene, pyrene, fluoranthene and chrysene were consistently detected in mussels at the Pettit Flume inlet cove.

Figure 3: Caged Mussel Tissue Concentrations (mean±SD, n=3)



Niagara River, 1985-1997

Pettit Flume

ND= Not Dectected

TABLE 4: Range in concentrations (ng/g wet weight) of polycyclic aromatic hydrocarbons in mussels introduced to the Niagara River for three weeks, 1997. If all the replicate samples were above the detection limit the mean and standard deviation was also provided.

Parameters	Detection Limit	Two Mile Creek	Mean	SD	Tonawanda Channel	Pettit Flume	Mean	SD	Buffalo R	Mean	SD
Acenaphthene	20	.			(.)-40	.			.		
Benzo(a) Anthracene	20	(.)-40			.	80-100	93	11.5	.		
Benzo(b) Fluoranthene	20	60-80	73	11.5	.	.			.		
Benzo(b/k) Fluoranthene	20	(.)-40			.	.			.		
Chrysene	20	160-220	187	30.6	.	500-600	540	52.9	40-60	47	11.5
Fluoranthene	20	200-280	233	41.6	.	340-440	400	52.9	.		
Benzo (g-h-i) Perylene	40	.			.	120-160	133	23.1	.		
Indeno (1,2,3-cd) Pyrene	40	.			.	(.)-80			.		
Phenanthrene	20	60-80	67	11.5	.	120-160	153	30.6	.		
Pyrene	20	140-200	167	30.6	.	220-300	260	40.0	(.)-40		

Acenaphthylene, anthracene, benzo(a)pyrene, dibenzo(ah)anthracene, fluorene and naphthalene were not detected in any samples

PAHs were not detected in mussels deployed at Fort Erie, Chippawa Channel, NOTL, 102nd Street upstream site and at 102nd Street landfill site.

The presence of PAHs in mussels deployed in the Pettit Flume cove at concentrations consistent with values prior to site remediation suggests that the source of PAHs was still present and was likely unrelated to the source of chlorinated benzenes, phenols, chlorotoluenes and other organic compounds previously contaminating the cove. The source of the chlorinated compounds was believed to be several hazardous waste sites located on the property of the Occidental Chemical Corporation-Durez Division in North Tonawanda. The Pettit Flume is a storm sewer which drains much of North Tonawanda suggesting that storm water runoff was likely the source of PAHs to the cove rather than the hazardous waste sites.

Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans

Dioxins and furans were analysed in sediment and one composite mussel sample (four mussels per site) from each of four sites and from the Balsam Lake control mussels. Dioxins and furans were not detected in the Balsam Lake control mussels or mussels deployed at Fort Erie. Sediment concentrations of dioxins and furans at the Fort Erie site were low and similar to concentrations measured in sediment in 1995 from Fort Erie (Table 5a & 5b). Particle size data and sediment % TOC are provided in Appendix E.

102nd Street Landfill Site

Concentrations of dioxins and furans in mussels deployed at 102nd Street Landfill were low and reflect the success of the site remediation. For many of the congener groups, concentrations in mussels were at least ten times lower than previous years of monitoring (Figure 4 & 5). Dioxins and furans were not detected in the sediment sample collected from the site.

Bloody Run Creek

At Bloody Run Creek concentrations of dioxins and furans in mussels were similar to concentrations detected in 1994 and 1995 following the completion of site remediation, and were less than concentrations found in mussels deployed in 1993. These results suggest that remedial actions taken to cover contaminated sediment on the river bank have reduced the bioavailability of the dioxins and furans present.

Dioxins and furans in exposed shoreline (bank) sediment although lower than pre-remediation concentrations, were still extremely high relative to sediment concentrations throughout the Great Lakes basin including some of the most contaminated sites that have been identified by MOE (MOE unpublished data) (Figure 6 & 7). Characteristic of the congener/isomer patterns for Bloody Run Creek all the tetra-dioxin (T4CDD) was in the form of 2,3,7,8-tetrachlorodibenzo-p-dioxin which is the most toxic form of dioxin. Concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin were 45,000 pg/g (Figure 8 & 9).

TABLE 5a: Concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in mussels introduced to the Niagara River for three weeks, 1997.

Concentrations are in pg/g (wet weight). n=1

Parameters	Fort Erie Robertson Street (Ont.)	Pettit Flume (NY)	Bloody Run Creek (NY)	102nd Street (NY)
T4CDD (total)	.	220 (12)	83(2)	13(5)
P5CDD (total)	.	67(12)	11(3)	2.5(2)
H6CDD (total)	.	37(8)	24(6)	.
H7CDD (total)	.	16(2)	21(2)	.
O8CDD (total)	.	21	11	3
T4CDF (total)	.	420(17)	32(17)	25(17)
P5CDF (total)	.	330(15)	18(11)	10(7)
H6CDF (total)	.	310(11)	5(3)	6.1(2)
H7CDF (total)	.	300(4)	3.4(2)	5.9(1)
O8CDF (total)	.	280	5.9	6.3
2378T4CDD	.	3.4	81	.
2378T4CDF	.	62	2.6	2.5
12378P5CDD	.	3.4	2.1	.
12378P5CDF	.	10	.	.
23478P5CDF	.	29	1.4	1.1
123478H6CDD	.	1.7	.	.
123678H6CDD	.	3.2	6.5	.
123789H6CDD	.	2.3	3.1	.
234678H6CDF	.	7.2	.	.
123478H6CDF	.	150	3	3.2
123678H6CDF	.	23	.	.
123789H6CDF	.	.	.	.
1234678H7CDD	.	9.4	14	.
1234678H7CDF	.	240	2.1	5.9
1234789HCDF	.	7.6	.	.

( )Number of isomers detected in the congener group

"." Compound was below the detection limit

TABLE 5b: Concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in sediment from the Niagara River, 1997. Concentrations are in pg/g (dry weight). n=1

Parameters	Fort Erie Robertson Street (Ont.)	Pettit Flume (NY)	Bloody Run Creek (NY)	102nd Street (NY)
T4CDD (total)	10(3)	1100(11)	45000(5)	.
P5CDD (total)	2.3(2)	4200(12)	14000(12)	.
H6CDD (total)	25(6)	22000(8)	180000(8)	.
H7CDD (total)	54(2)	14000(2)	230000(2)	.
O8CDD (total)	160	21000	150000	.
T4CDF (total)	20(21)	4000(15)	4400(17)	.
P5CDF (total)	30(9)	17000(15)	39000(15)	.
H6CDF (total)	14(3)	110000(10)	55000(14)	.
H7CDF (total)	4.8(1)	360000(4)	35000(4)	.
O8CDF (total)	.	540000	74000	.
2378T4CDD	8.9	350	45000	.
2378T4CDF	2.5	1300	810	.
12378P5CDD	.	790	740	.
12378P5CDF	.	2600	750	.
23478P5CDF	2.1	6300	2500	.
123478H6CDD	.	760	2900	.
123678H6CDD	4.9	1600	42000	.
123789H6CDD	2.8	3400	23000	.
234678H6CDF	.	3900	930	.
123478H6CDF	.	97000	24000	.
123678H6CDF	.	14000	4100	.
123789H6CDF	.	130	79	.
1234678H7CDD	34	8800	150000	.
1234678H7CDF	.	320000	16000	.
1234789HCDF	.	10000	5100	.

( )Number of isomers detected in the congener group

"." Compound was below the detection limit

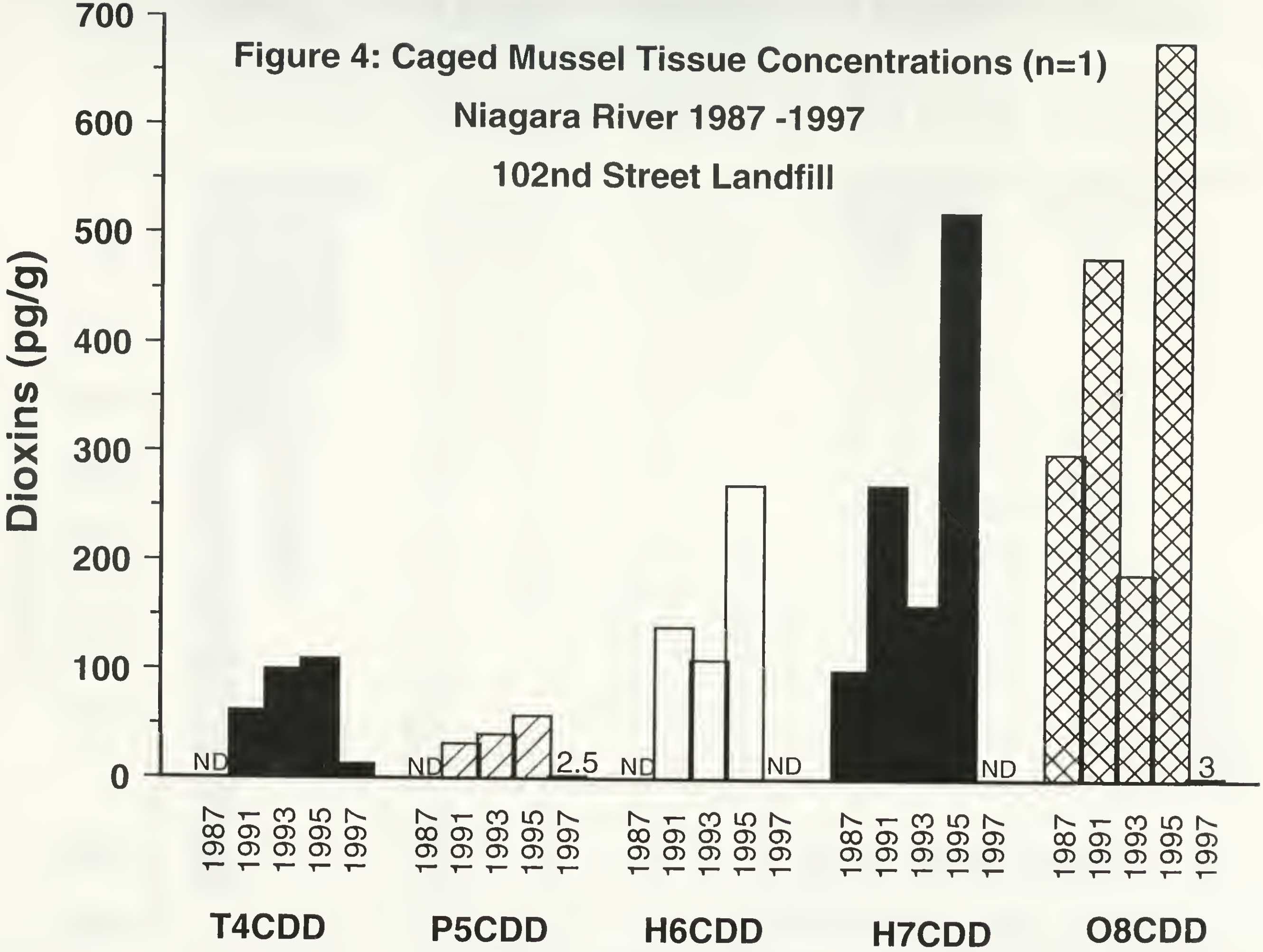


Figure 4: Caged Mussel Tissue Concentrations (n=1)

Niagara River 1987 -1997

102nd Street Landfill

Figure 5: Caged Mussel Tissue Concentrations (n=1)

Niagara River 1987 -1997

102nd Street Landfill

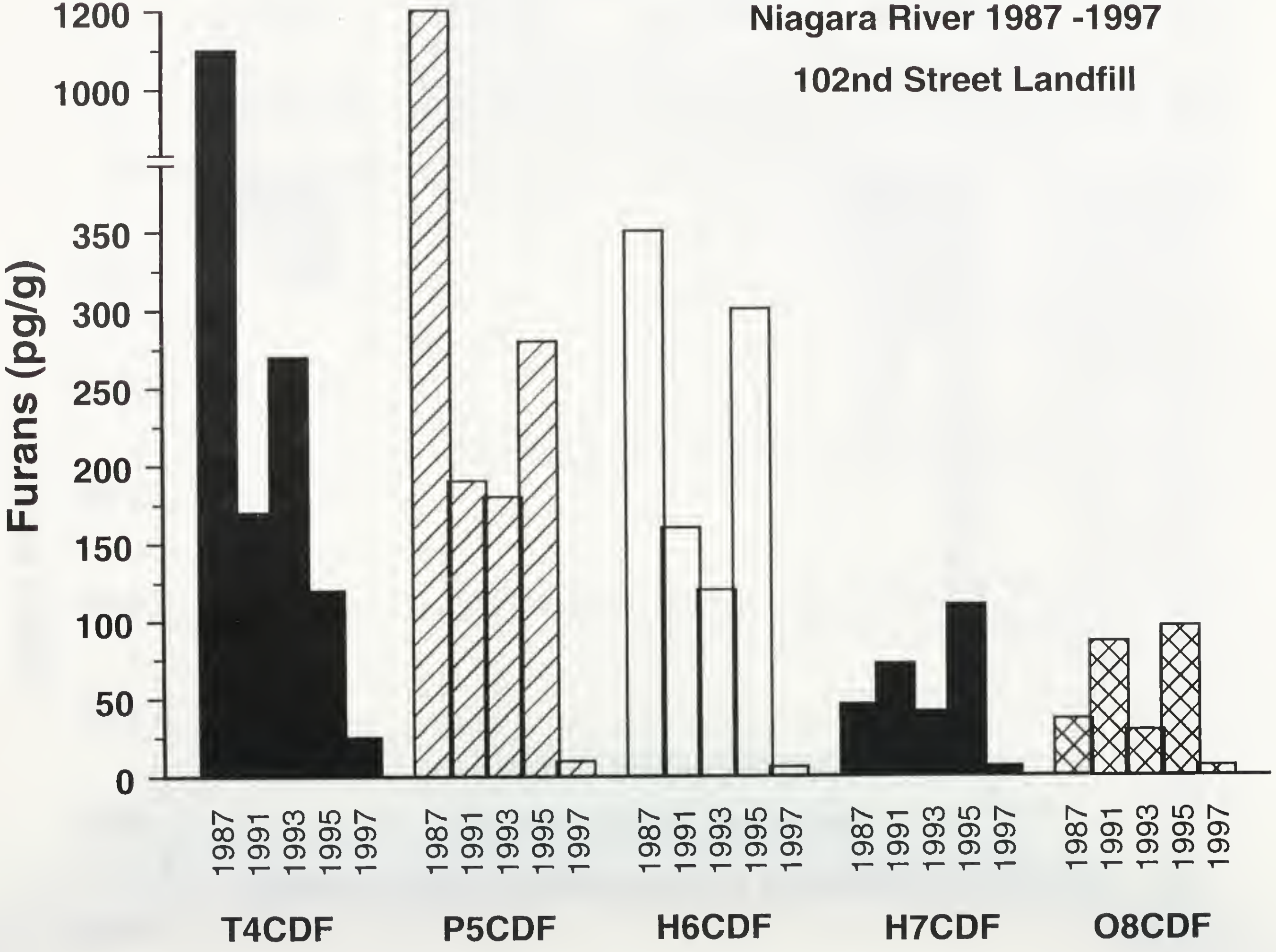


Figure 6: Dioxin Concentrations (ng/g) in Sediment (n=1)

Niagara River 1993 -1997

Bloody Run Creek

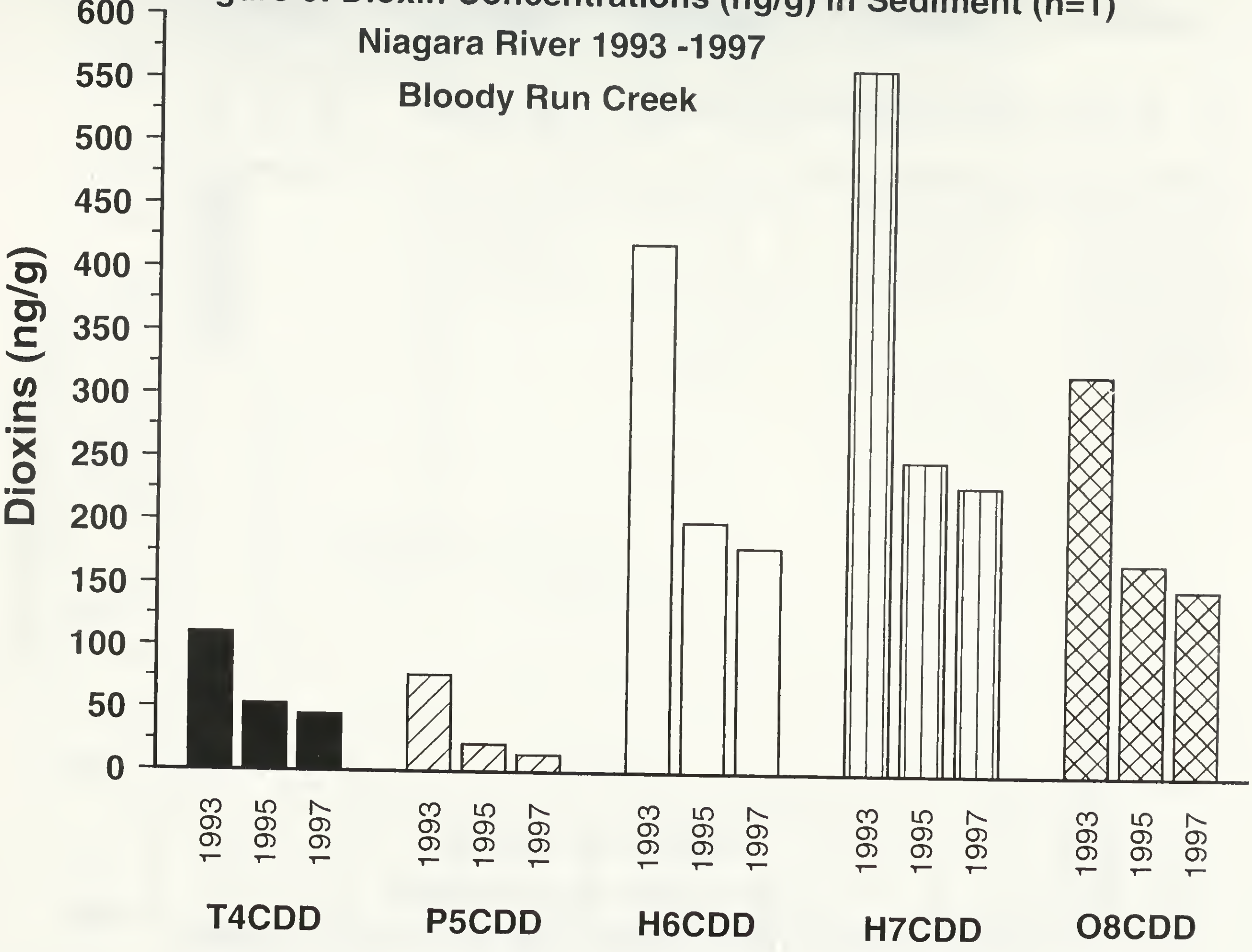


Figure 7: Furan Concentrations (ng/g) in Sediment (n=1)
Niagara River 1993 -1997
Bloody Run Creek

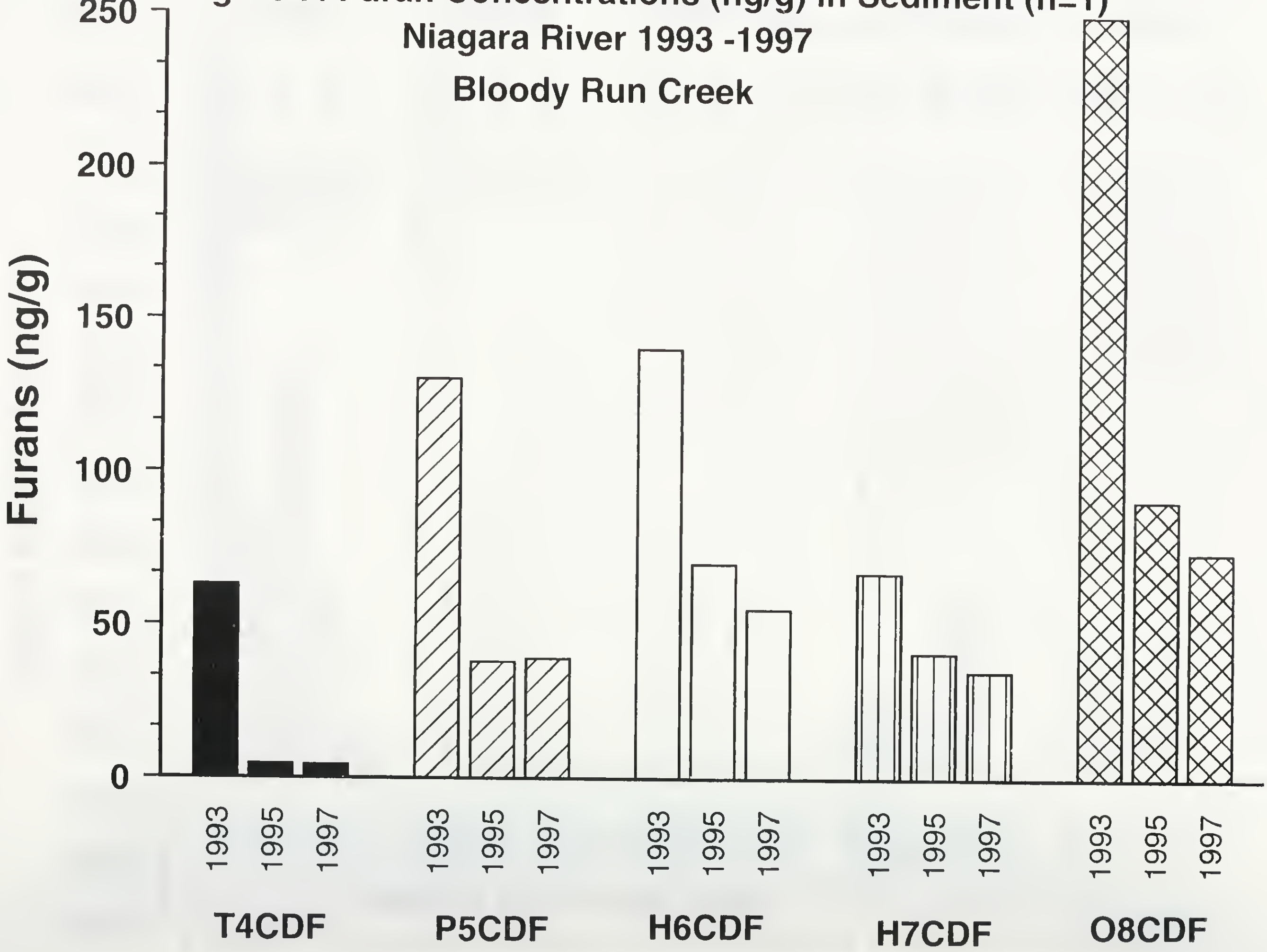


Figure 8: Isomer Patterns in Mussels
Bloody Run Creek (1997)

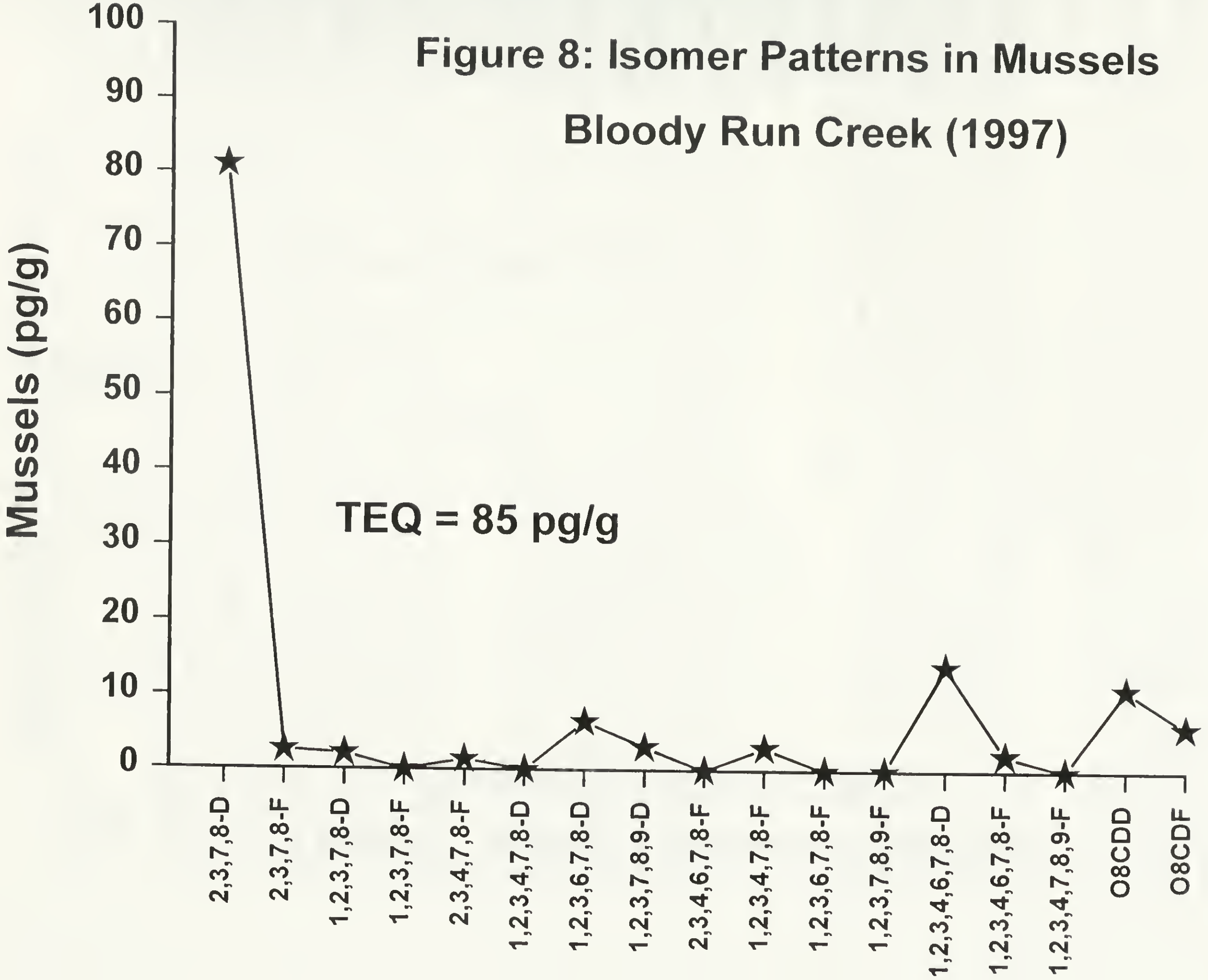
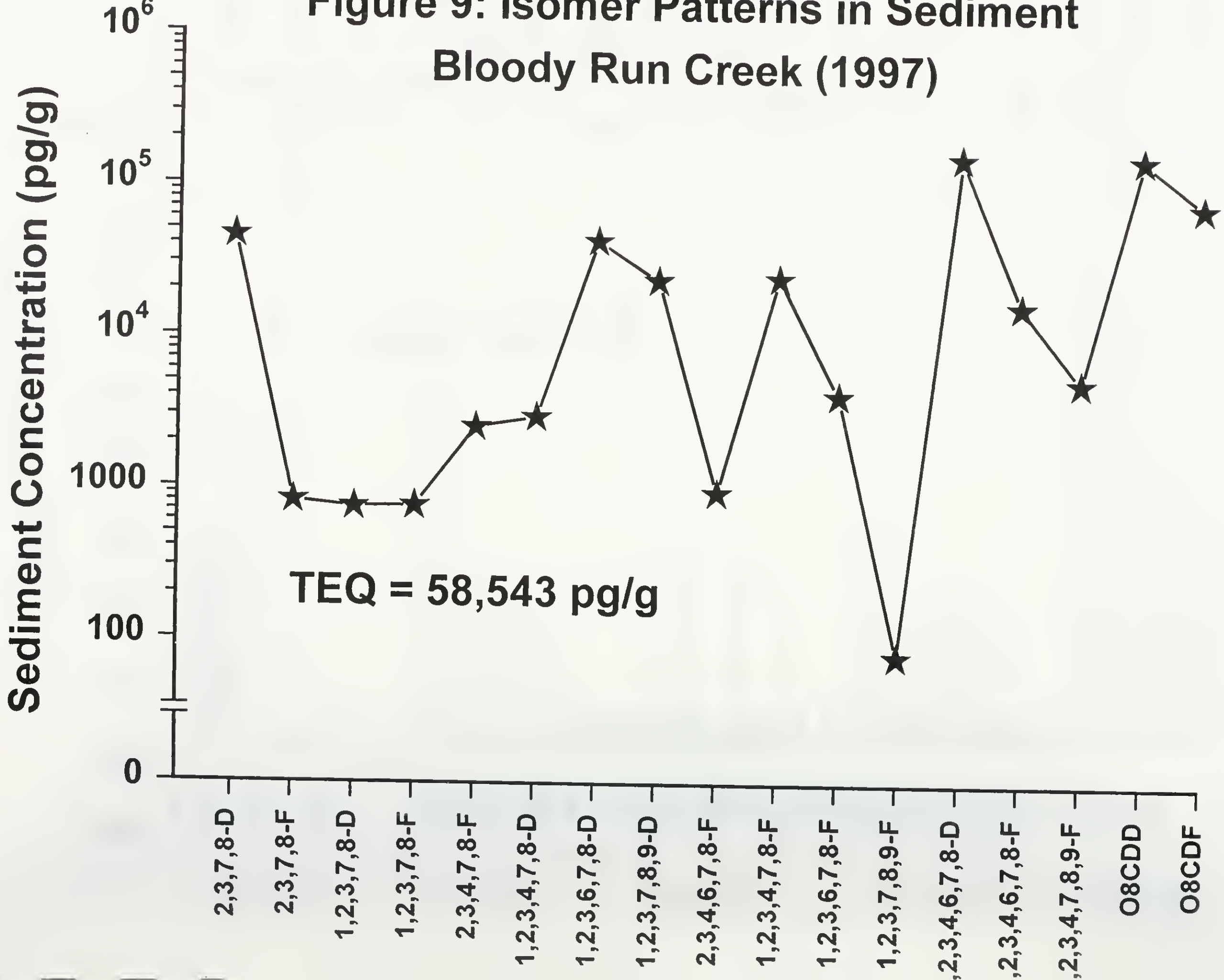


Figure 9: Isomer Patterns in Sediment
Bloody Run Creek (1997)



Concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin in sediment at Bloody Run Creek were 5000 times higher than concentrations at Fort Erie which was a relatively uncontaminated site. Concentrations of penta-, hexa- and hepta- chlorodibenzo-p-dioxin were at least 6,000, 7,000 and 4,000 times higher (respectively) than concentrations at Fort Erie. Sediment at Bloody Run Creek typically has higher concentrations of dioxins than furans with hexa- and hepta- the predominant compounds.

This sediment is of concern because of the high concentrations of 2,3,7,8 tetra-chlorodibenzo-p-dioxin. The total TEQ (concentration of toxicity equivalents using the World Health Organization TEFs from August 1997), for the sediment was 58,543 pg/g. This sediment sample was collected from the shoreline of the Niagara River. This portion of the shoreline is routinely underwater since the water levels fluctuate daily to maintain the operation of the hydro generating stations making it susceptible to erosion. The presence of dioxins and furans in mussels at this site suggest that these compounds were bioavailable to the Niagara River.

Pettit Flume

High concentrations of dioxins and furans were detected in mussels and sediment from the Pettit Flume inlet cove. The source of the dioxins and furans is unclear given the recent extensive remedial activities at this site but may be due to infiltration of contaminants to the Pettit Flume (storm sewer) from contaminated groundwater or contaminated bedding surrounding the sewer. The Pettit Flume discharges storm water to the Pettit Flume inlet cove. The return of high concentrations of contaminants to the cove has been confirmed by NYSDEC and EPA (G. Kline, New York State Department of Environmental Conservation, Albany and S. Ausubel, United States Environmental Protection Agency, New York City, personal communication). NYSDEC is presently investigating possible sources and the extent of contamination in the cove.

Concentrations of dioxins and furans in mussels deployed at the Pettit Flume cove in 1997 were at least three times lower than concentrations detected in 1993, and the 2,3,7,8-chlorine substituted isomer was four times lower indicating that remedial activities were successful. However, the concentrations were still uncharacteristically high for a remediated site which suggested that the site was re-contaminated after the remediation. Dioxin and furan concentrations in mussels and sediment were high compared to other sites monitored in this survey and compared with sites monitored in previous MOE mussel and sediment surveys throughout the Great Lakes basin. The high concentrations in mussel tissue suggest that these compounds were still bioavailable in this cove. Fish, other aquatic biota and waterfowl move freely in and out of the cove to feed, and sediment is transported from the cove to the Little Niagara River. All these factors suggest that dioxins and furans in this cove were likely bioavailable to the Niagara River.

The isomer patterns in the sediment and mussel samples were consistent with previous samples from 1993 before remedial activities which suggests a common source (Figure10 & 11).

Figure 10: Isomer Patterns in Mussels - Pettit Flume

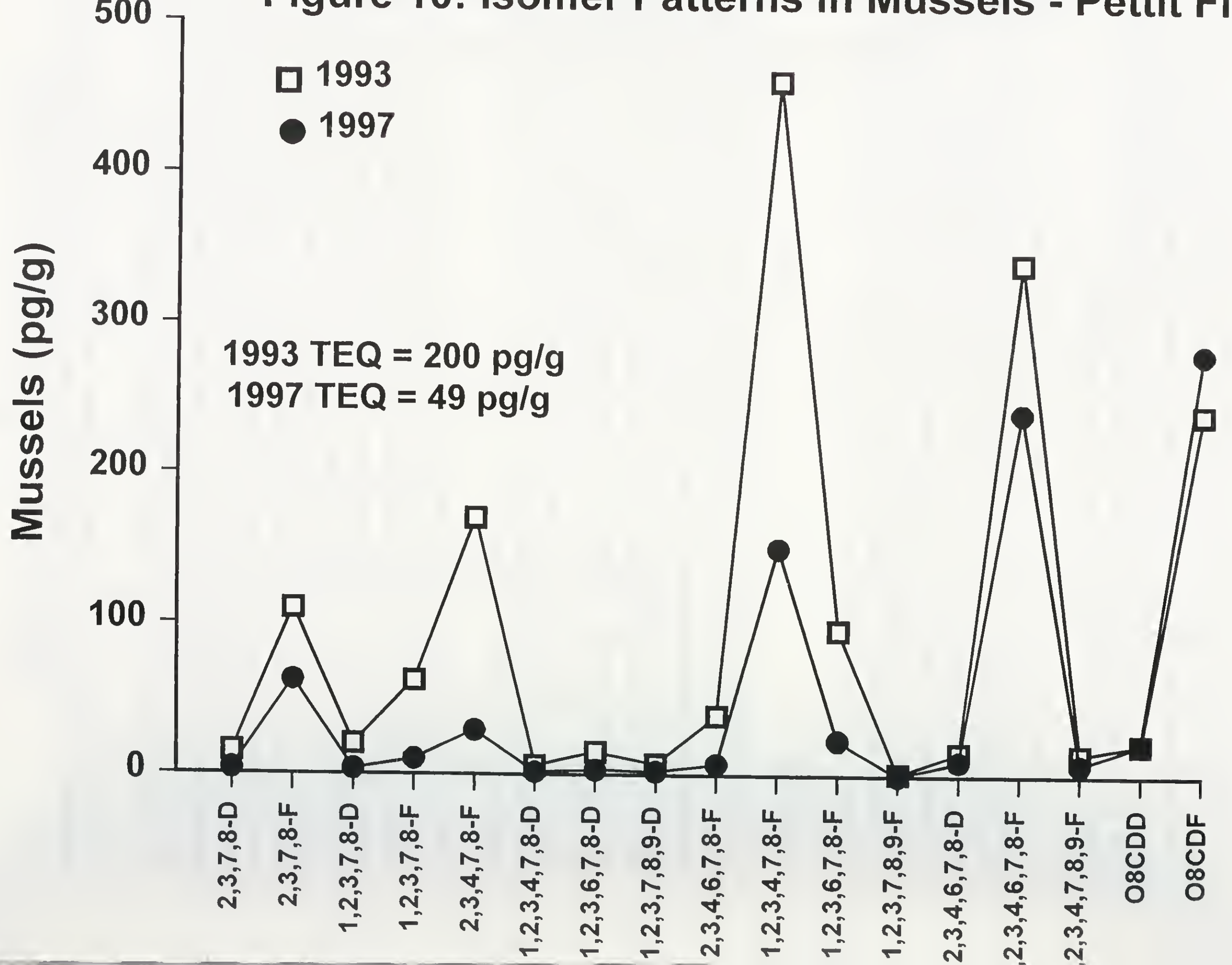
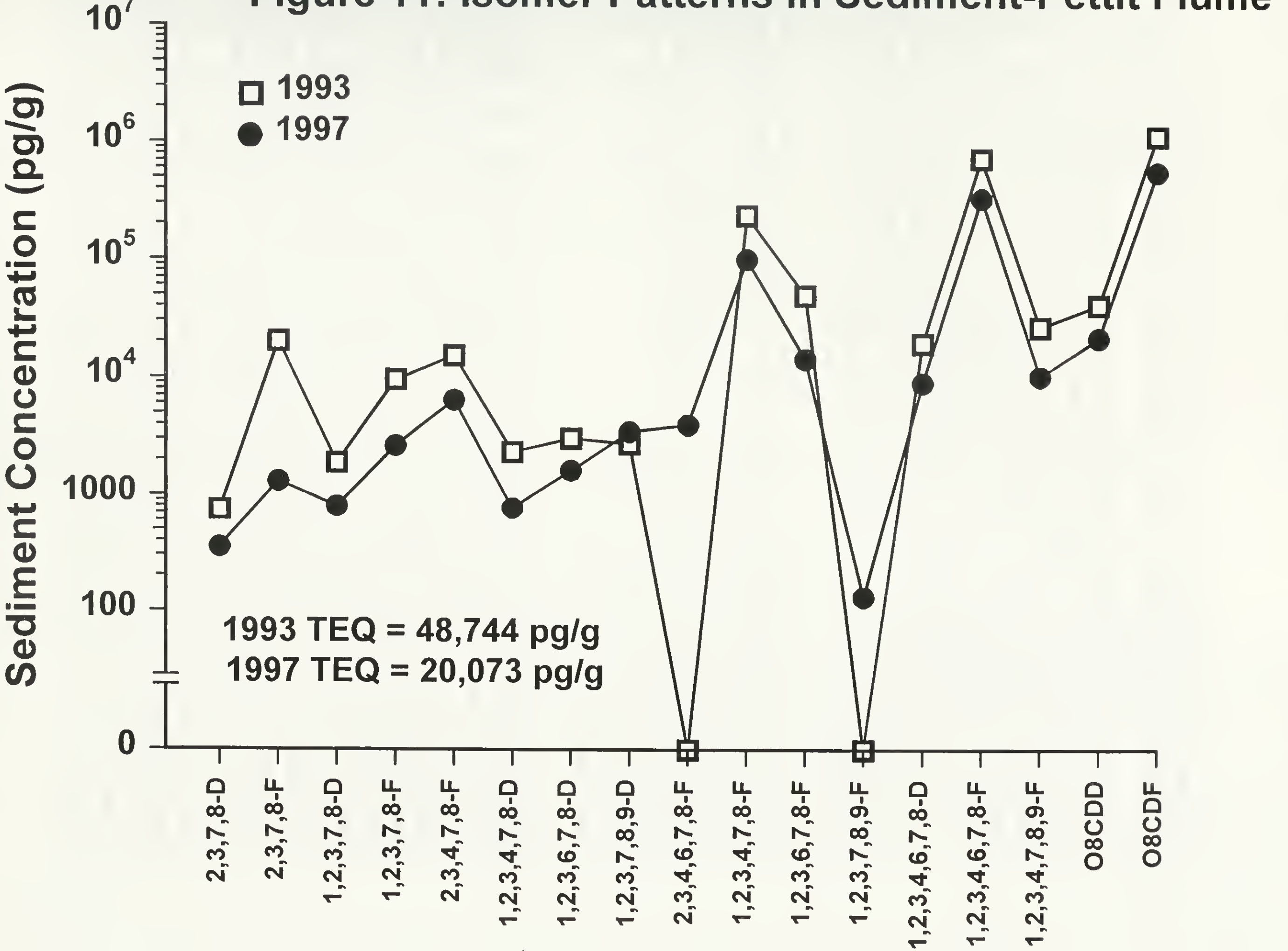


Figure 11: Isomer Patterns in Sediment-Pettit Flume



Sediment from the Pettit Flume cove typically have higher concentrations of furans than dioxins with the hexa-, hepta- and octa- dibenzofurans the predominant compounds.

A comparison of 1997 sediment data with sediment collected immediately upstream of the Pettit Flume at a reference station in1993 showed that for most congener groups the Pettit Flume sediment was 15 to 200 times more contaminated than the upstream sediment while some congener groups were even higher. In particular, 2,3,7,8 T4CDD was not detected in sediment from the Pettit Flume upstream station while concentrations in sediment from the Pettit Flume site were 350 pg/g. For comparison, concentrations of 2,3,7,8 T4CDD at Fort Erie were 8.2 pg/g and at Bloody Run Creek they were 45,000 pg/g. In general, concentrations of 2,3,7,8 T4CDD throughout the Great Lakes Basin tend to be less than 10 pg/g (MOE unpublished data). A sediment survey of 49 stations in Lake Ontario reported the mean sediment concentration of 2,3,7,8 T4CDD was 68 pg/g with only one sample as high as 350 pg/g (U.S. EPA et. al. 1990).

When concentrations of individual isomers were converted to toxicity equivalents of 2,3,7,8-T4CDD (TEQ) the mussels at Bloody Run Creek had almost two times the toxic equivalency as mussels at the Pettit Flume cove. The same is true for contaminated sediment from both sites with the Bloody Run Creek sediment having more than two times the toxic equivalency as the Pettit Flume cove sediment and at least 5000 times greater TEQ than the Fort Erie sediment. The TEQ for the Pettit Flume cove sediment was 20,073 pg/g and for Fort Erie it was 11.4 pg/g.

Long Term Deployment of Caged Mussels

Mussels were deployed for up to 127 days at four sites on the American side of the River; Gratwick Riverside Park, the 102nd Street Landfill site, in Cayuga Creek and at the mouth of Two Mile Creek. Gratwick Riverside Park is a hazardous waste site and is a source of contaminants to the Niagara River (US EPA & NYSDEC 1998). In general contaminant concentrations in mussels deployed at this site during previous monitoring surveys have been low or below the detection limit for most parameters. This station was chosen for long term monitoring to help determine if the station was adequately reflecting contaminant leaching from the waste site or if it was reflecting general background concentrations for the river. The 102nd Street site was chosen as a follow up to the 1995 long term survey and to investigate the site after remedial activities were completed. Two Mile Creek was monitored to obtain additional information on the creek as a source of PCBs and Cayuga Creek was chosen because it represented a tributary that was historically contaminated.

Mussels deployed at the 102nd Street Landfill accumulated hexachlorobenzene after 14 days of exposure compared with mussels from Cayuga Creek and Gratwick Riverside Park which accumulated hexachlorobenzene after 7 days of exposure (Table 6). At all sites concentrations were close to the detection limit and remained the same throughout the survey (range from below the detection limit to 3 ng/g). Tissue concentrations of pp'-DDE

TABLE 6: Range in concentrations (ng/g wet weight) of contaminants detected in mussels introduced to the Niagara River for varied deployment times, 1997. Mussels deployed in Two Mile Creek were only analysed for PCB contamination.

	Hexa-chlorobenzne	Penta-chlorobenzene	Octachloro-styrene	α–BHC	β–BHC	Total PCBs	pp'-DDE
102nd Street Landfill Deployment	Range	Range	Range	Range	Range	Range	Range
1 day	.	.	.	.	.	.	.
2 days	.	.	.	.	.	.	.
3 days	.	.	.	.	.	.	.
7 days	.	.	.	.	.	(.) - 40	(.) - 6
14 days	(.) - 2	.	.	.	.	40 - 80	.
21 days	.	.	(.) - 2	.	.	20 - 40	(.) - 2
28 days	(.) - 2	.	.	.	.	40 - 60	.
56 days	(.) - 3	.	.	.	.	60	.
98 days	(.) - 2	.	.	.	.	60 - 140	.
Cayuga Creek Deployment	Range	Range	Range	Range	Range	Range	Range
1 day	.	.	.	.	.	.	.
2 days	.	.	.	.	.	.	.
3 days	.	.	.	.	.	.	.
7 days	2	.	.	.	.	40 - 80	(.) - 2
14 days	3	(.) - 2	.	.	.	100 - 120	.
21 days	2-3	2	(.) - 2	5-8	5-8	40 - 60	3 - 4
28 days	2-3	.	.	.	.	80 - 100	(.) - 2
56 days	(.) - 3	.	.	.	.	60 - 120	(.) - 3
98 days	2-3	.	.	.	.	140 - 160	(.) - 3
127 days	2	.	.	.	.	140 - 200	(.) - 3

Table 6 continued.

	Hexa-chlorobenzne	Penta-chlorobenzene	Octachloro-styrene	α–BHC	β–BHC	Total PCBs	pp'-DDE
Gratwick Riverside Pk. Deployment	Range	Range	Range	Range	Range	Range	Range
1 day	.	.	.	.	.	.	.
2 days	.	.	.	.	.	.	.
3 days	.	.	.	.	.	.	.
7 days	2	.	.	.	.	40 - 60	.
14 days	2	.	.	.	.	80 - 100	(.) - 4
21 days	.	.	2	.	.	40	(.) - 3
28 days	(.) - 3	.	.	.	.	100 - 120	.
56 days	(.) - 2	.	.	.	.	100	.
98 days	(.) - 2	.	.	.	.	60 - 100	.
127 days	(.) - 2	.	.	.	.	60 - 80	.

Two Mile Creek Deployment	Range	Range	Range	Range	Range	Range	Range
1 day						.	
3 days						40 - 60	
7 days						60 - 80	
21 days						80 - 100	
28 days						140 - 160	

n=3 for all sampling events

"." Compound was below the detection limit

followed the same pattern as hexachlorobenzene at Cayuga Creek and although concentrations were similar at all three sites, pp'-DDE was only detected on two occasions at the other two sites.

Trace concentrations of pentachlorobenzene and α-BHC and β-BHC were only detected in mussels deployed at Cayuga Creek. α-BHC and β-BHC were only detected at the 21 day retrieval. These results were consistent with data from the 21 day deployment at Cayuga Creek in 1995, although trace concentrations of chlordane were also detected in 1995 but were absent in 1997.

Concentrations of hexachlorobenzene and pp'-DDE at the Gratwick Riverside Park sampling station in 1997 were consistent with the results from past surveys and concentrations in mussels were similar to the mussels deployed at a reference site immediately upstream of the park. The results from the long term survey, previous 21 day deployment surveys at this site and a comparison of data with the upstream reference site suggest that the mussel monitoring station for this waste site may be reflecting background contaminant concentrations for the river instead of the release of contaminants from the waste site, and should be relocated.

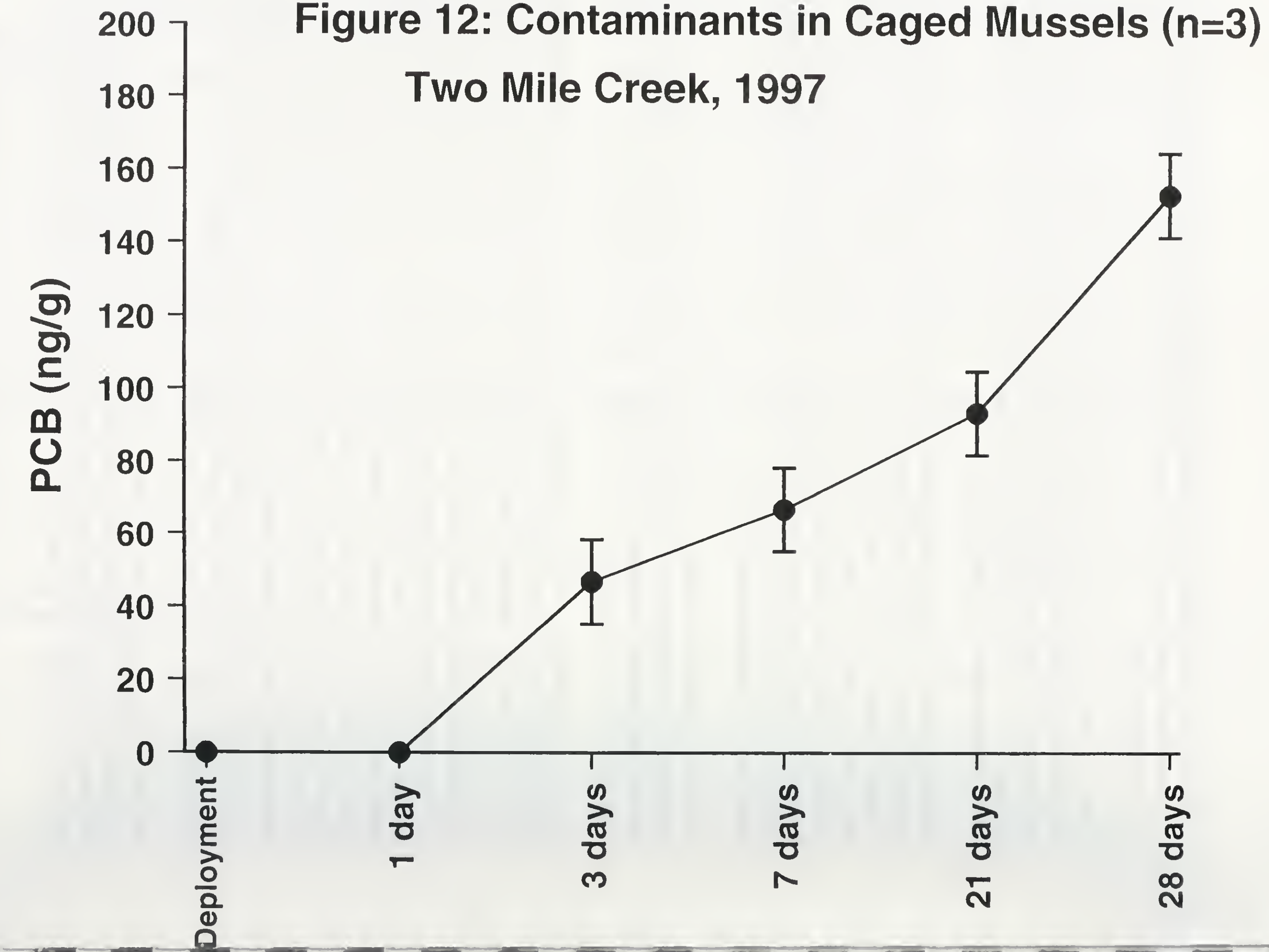
PCBs were detected in mussels deployed at all four sites. Tissue concentrations of PCBs were below the detection limit (20 ng/g) for the first day of sampling at Two Mile Creek and then concentrations increased until the final day of available data at day 28. Tissue concentrations had not levelled off by 28 days of exposure (Figure 12).

Tissue concentrations of PCBs were either below or recorded at the detection limit for the first three days of deployment at the remaining three stations and then began to increase by day 7 (Figure 13). Although initial patterns of uptake were similar at the three stations actual tissue concentrations differed. Results from a two-way ANOVA using log-transformed PCB tissue concentrations in mussels deployed at the three sites suggest that PCB concentrations varied with the number of days deployed but the relationships differed among the sites. The two factors in the ANOVA were day and site. The statistically significant ($p<0.001$) interaction between the two factors suggest that the rate of PCB uptake differed among the sites over time. For example, concentrations in mussels at Gratwick Riverside Park peaked at 14 and 28 days of exposure and appeared to have reached equilibrium, remained stable until 56 days of exposure and then began to decrease at 98 and 127 days (mean at 127 days-73 ng/g, SD 11.5 ng/g). Concentrations in mussels at Cayuga Creek also appeared to have reached equilibrium after 28 and 56 days of deployment but then concentrations continued to increase after 98 and 127 days of exposure (mean at 127 days-173 ng/g, SD 30.5 ng/g).

This general pattern of bioaccumulation (rapid initial uptake between 3 and 14 days of exposure and then a levelling off of tissue concentrations), was more representative of a continuous low level source than short term contaminant pulses entering the aquatic environment. It is also characteristic of a parameter with a high octanol-water partition

Figure 12: Contaminants in Caged Mussels (n=3)

Two Mile Creek, 1997



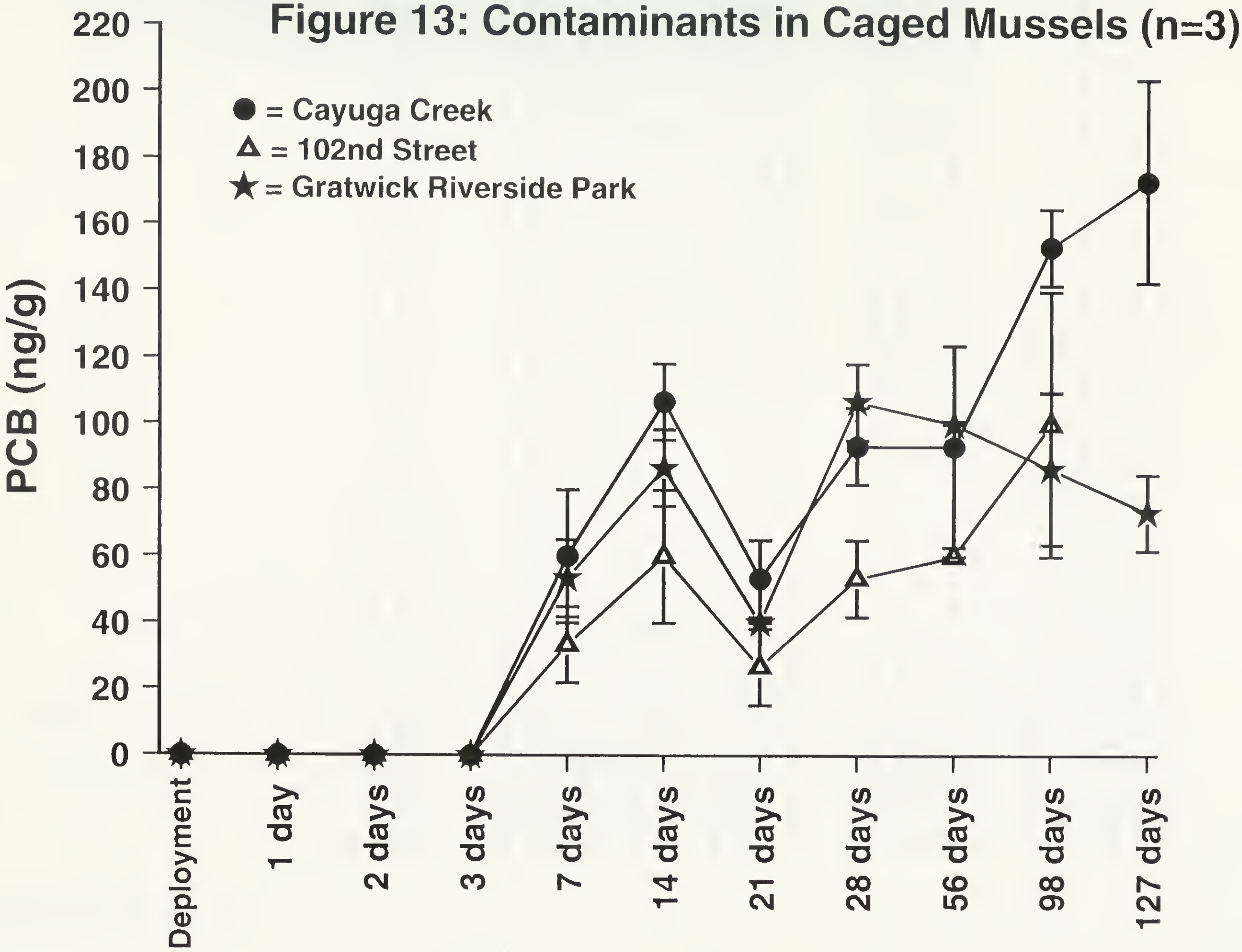


Figure 13: Contaminants in Caged Mussels (n=3)

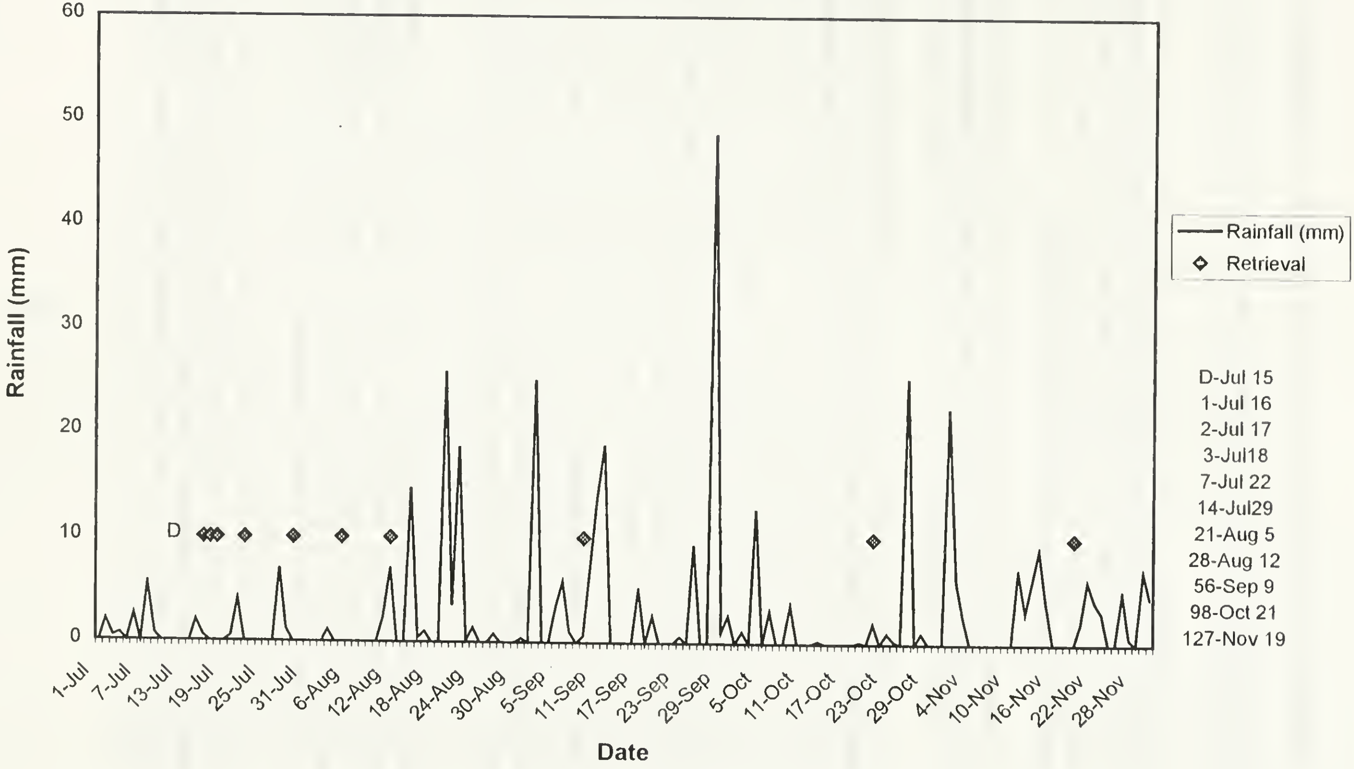
coefficient (log K_{ow}) such as PCBs (Oliver 1987; Hawker and Connell 1985). However, these results suggests that the 21 day exposure survey may be insufficient to assess maximum bioaccumulation of PCBs at some stations (Kauss and Angelow 1988; Richman 1997). Peven *et al.* (1996) also found that mussel PCB and total DDT tissue concentrations followed a similar pattern of bioaccumulation when mussels were transplanted from a relatively clean environment to a PCB contaminated bay.

A regression analysis on PCB concentrations and percent lipid levels at Cayuga Creek produced a r^2 of 0.7. This relationship was not as good at 102nd Street ($r^2 = 0.5$) and poor for Gratwick Riverside Park ($r^2 = 0.15$). Since the relationship between PCB tissue concentrations and lipid content was not consistent between sites, PCB tissue concentration data were not normalized for percent lipid. Percent lipid data are provided in Appendix B.

A plot of rainfall data for the Niagara Falls area (Environment Canada 1997) with mussel deployment/retrieval times suggests that contaminant uptake patterns for PCBs and pp'-DDE did not reflect a response to rain events (Figure 14). This is consistent with PCB and pp'-DDE results from the 1995 survey (Richman 1997). The uptake patterns of hexachlorobenzene did not correspond with rainfall events as well (in contrast to the 1995 survey involving a non-point source). However, this was likely due to the low tissue concentrations present in the mussels which reflected low concentrations in their surrounding environment. Also, a review of the rainfall data showed that large rain events that may have caused a mobilization of contaminants into the surrounding water and subsequent bioaccumulation in mussels did not occur near any of the mussel sampling events. A tissue response to elevated water concentrations would likely have been missed since retrieval of mussels typically occurred at least one to two weeks following a large rain event.

Water temperature and dissolved oxygen concentrations at all stations were similar and did not appear to have influenced contaminant tissue concentrations. Conductivity varied between stations with the highest levels at Cayuga Creek and Two Mile Creek (Appendix C).

Figure 14: Rainfall (mm) in Niagara Falls, Ontario, 1997 and Caged Mussel Deployment Retrieval Date



D = Deployment Date
1 to 127 = length of deployment in days.

SUMMARY OF SIGNIFICANT FINDINGS AND RECOMMENDATIONS

1) Trace concentrations of p,p'-DDE were detected in mussels introduced on the Canadian side of the river.

2) Organochlorine pesticides were detected sporadically at several stations at concentrations previously detected in other surveys, while PCBs and chlorinated benzene compounds were detected at almost all stations on the American side of the river. The most frequently detected chlorinated benzenes were; hexachlorobenzene, pentachlorobenzene and 1,2,3,4-tetrachlorobenzene.

3) Tissue concentrations of most parameters were below the detection limit at the 102nd Street Landfill site when mussels were deployed after remedial activities were completed in contrast to high concentrations previously detected in caged mussels.

4) Concentrations of chlorinated benzenes in mussels deployed at the Pettit Flume inlet cove were low. This showed that the remediation was successful at improving the water quality of the cove. By removing contaminated sediment from the cove an important non point source of chlorinated benzenes and phenols to the Niagara River was eliminated.

High concentrations of dioxins and furans were detected in mussels and sediment from the Pettit Flume inlet cove. The source of the dioxins and furans is unclear given the recent extensive remedial activities at this site. The TEQ for the Pettit Flume cove sediment was 20,073 pg/g. Future mussel surveys should include additional monitoring of this site and include dioxin/furan analysis of mussels and sediment at the upstream reference site.

5) Dioxin and furan concentrations in sediment from the Niagara River shoreline at the Bloody Run Creek site were lower than before remediation but still remain a concern since the sediment contains high concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (45,000 pg/g). The TEQ for the sediment was 58,543 pg/g. Continued monitoring of this site and an upstream reference site is recommended for future surveys.

6) The results from the long term four month survey, previous 21 day deployment surveys and a comparison of data with the upstream reference site suggest that the mussel monitoring station for Gratwick Riverside Park hazardous waste site may be reflecting background contaminant concentrations for the river instead of the release of contaminants from the waste site, and should be relocated.

7) The mussel monitoring program will be repeated in July 2000 as per recommendations from the 1995 report to carry out surveys every three years rather than the original schedule of every two years. This new monitoring schedule will be consistent with other ongoing MOE Great Lakes monitoring activities within the Environmental Monitoring and Reporting Branch.

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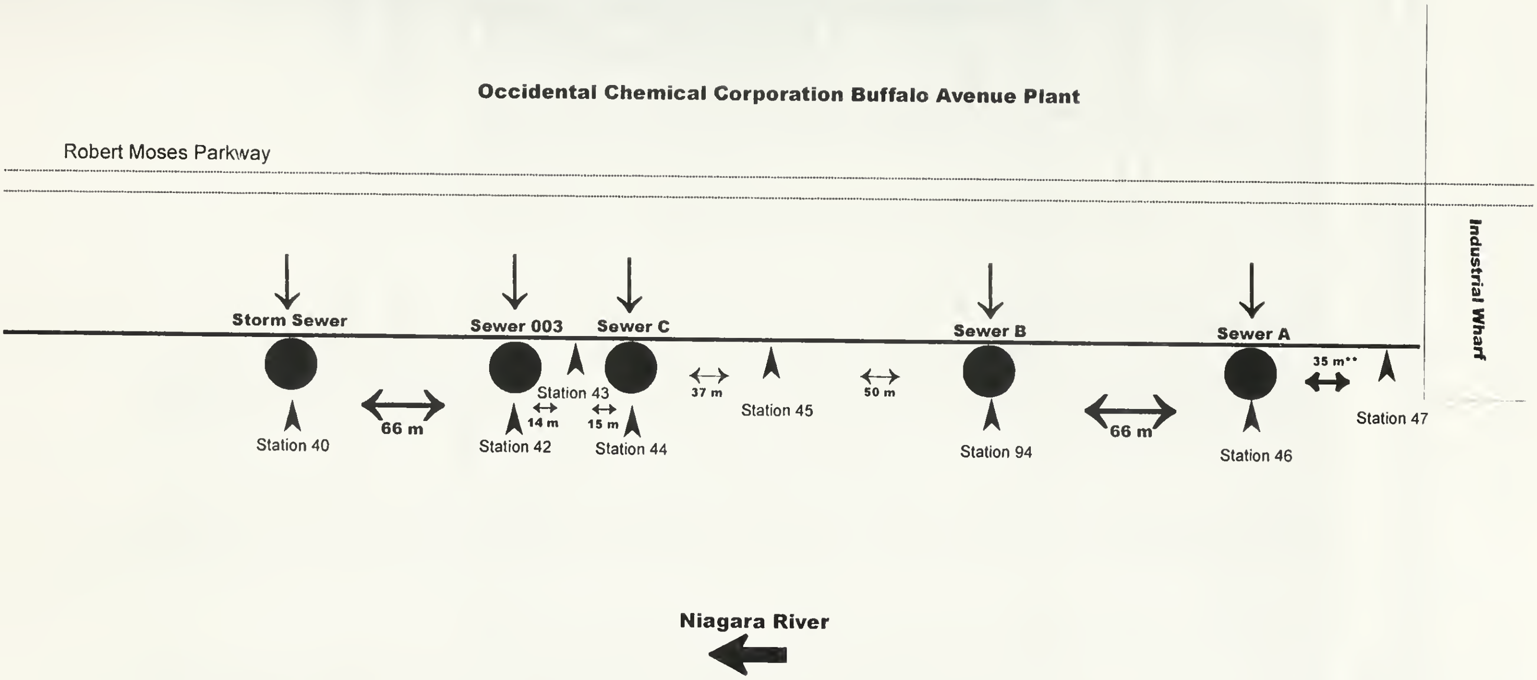
APPENDICES

APPENDIX A: Information on Station Location.

Station Name	Station Number		Latitude	Longitude	UTMs	
			degree-min.-sec.	degree-min.-sec.	Northing	Easting
Canadian Sites						
Fort Erie at Robertson St.	203		42-55-41.2206	78-54-48.336	4754944.5N	670274.1E
Black Creek (mouth)	193		42-58-48.1884	79-01-26.856	4760493.8N	661104.5E
Welland River - Atlas Steel (outfall)	15-21	Mussels were not retrieved	43-00-4.308	79-14-25.9494	4762449.7N	643409.4E
Chippawa Channel	51		43-02-58.4244	79-01-13.8174	4768220.1N	661217.9E
NOTL	9		43-15-13.869	79-03-36.5868	4790832.2N	657462.3E
US Sites						
Buffalo River (mouth)	196		42-52-39.225	78-53-3.2706	4749389.9N	672797.0E
Black Rock Canal	91	Mussels were not retrieved	42-53-56.382	78-54-7.02	4751733.8N	671291.3E
Tonawanda Channel (upstream of stn 92) - outfall	3	Mussels were not retrieved	43-00-29.781	78-54-51.7236	4763844.132N	669976.318E
Tonawanda Channel (upstream of ck)	92		43-00-31.3878	78-54-47.895	4763895.852N	670061.763E
Two Mile Creek (mouth)	197		43-00-36.0072	78-54-24.276	4764051.663N	670592.922E
Ellicott Creek (Columbus - McKinnon Corp.)	15-32	Mussels were not retrieved	43-01-3.0102	78-52-9.7902	4764961.2N	673616.4E
Pettit Flume (upstream)	185		43-02-01.6512	78-53-07.4412	4766737.228N	672265.799E
Pettit Flume (site B)	186		43-02-03.4518	78-53-08.0658	4766792.418N	672250.265E
Sewer downstream of Superior Lubricant	4	Mussels were not retrieved	43-03-03.138	78-53-44.9664	4768612.655N	671369.043E
Gratwick/Riverside Park (upstream)	31		43-03-7.1244	78-53-51.3498	4768732.008N	671221.545E
Gratwick/Riverside Park	199		43-03-25.6326	78-54-16.9308	4769288.479N	670628.561E
102nd Street (upstream)	93		43-04-16.2474	78-56-42.0642	4770768.652N	667307.207E
102nd Street	22		43-04-22.8558	78-57-04.035	4770960.353N	666805.334E
Cayuga Creek	31		43-04-52.7352	78-57-38.523	4771863.077N	666002.959E
(Occidental) - upstream of Sewer A	47		43-04-29.1492	79-00-18.1488	4771048.7N	662410.8E
(Occidental) - Sewer A	46		43-04-28.1514	79-00-18.9108	4771017.5N	662394.3E
(Occidental) - Sewer B	94		43-04-28.4892	79-00-21.801	4771026.3N	662328.7E
(Occidental) - between Sewer B & Sewer C	45		43-04-29.016	79-00-23.8674	4771041.5N	662281.5E
(Occidental) - Storm Sewer C	44		43-04-29.7006	79-00-25.2192	4771061.9N	662250.5E
(Occidental) - between Sewer C & Sewer 003	43		43-04-29.9742	79-00-25.7514	4771070N	662238.2E
Occidental's S. 003	42		43-04-29.8188	79-00-26.3286	4771065.0N	662225.3E
Storm Sewer	40		43-04-30.888	79-00-28.8546	4771096.5N	662167.4E
Gill Creek (upstream)	15-22	Mussels were not retrieved	43-05-4.341	79-01-25.416	4772098.240N	660864.000E
Gill Creek (mouth)	37		43-04-41.6082	79-01-34.236	4771392.3N	660681.0E
Bloody Run Creek (upstream)	11-18		43-08-20.1432	79-02-36.5934	4778100.719N	659113.539E
Bloody Run Creek	11-17		43-08-19.5768	79-02-36.4872	4778083.302N	659116.347E
Bloody Run Creek (downstream)	11-25	Mussels were not retrieved	43-08-21.879	79-02-31.4712	4778156.970N	659228.003E

Appendix A1: Location of mussel sampling stations at outfalls associated with the Occidental Chemical Corporation. Niagara River, 1997



↔ = Approximate distance between stations

** - GPS inaccurate due to heavy tree cover: paced distance estimated at 16 m.

Appendix B: Percent Lipid and PCB concentrations in mussels introduced to the Niagara River for various deployment times, 1997.

	Deployment	LIPID	Total PCBs		Deployment	LIPID	Total PCBs		Deployment	LIPID	Total PCBs
	Time	%	NG/G (wet wt.)		Time	%	NG/G (wet wt.)		Time	%	NG/G (wet wt.)
102nd St.	1 day	0.80		**Cayuga Ck.**	1 day	0.80		**Gratwick**	1 day	0.50	
		0.70				0.70		**Riverside**		0.50	
		0.90				0.70		**Park**		0.80	
	2 days	0.40			2 days	0.80			2 days	0.70	
		0.50				0.70				0.70	
		0.40				0.40				0.60	
	3 days	0.60	.		3 days	0.40	.		3 days	0.20	
		0.30				0.50				0.40	
		0.10				0.50				0.60	
	7 days	0.40	40		7 days	0.60	80		7 days	0.80	60
		0.20	40			0.80	60			0.80	60
		0.40	20			0.70	40			0.70	40
	14 days	0.80	40		14 days	1.30	100		14 days	0.60	80
		1.40	60			1.00	120			0.80	80
		1.50	80			1.30	100			0.90	100
	21 days	0.88	40		21 days	0.57	40		21 days	0.49	40
		0.36				0.85	60			0.66	40
		0.56				1.20	60			0.98	40
	28 days	0.60	40		28 days	1.30	80		28 days	0.80	100
		0.50	60			1.20	100			1.10	120
		1.00	60			1.10	100			0.80	100
	56 days	0.60	60		56 days	1.00	60		56 days	0.80	100
		1.10	60			1.30	120			0.70	100
		1.00	60			1.00	100			1.10	100
	98 days	1.90	140		98 days	2.00	140		98 days	1.00	100
		2.80	100			1.50	160			0.80	100
		2.00	60			1.70	160			2.10	60
					127 days	1.40	200		127 days	0.60	80
						1.50	180			2.00	80
						1.40	140			1.60	60

(.) - below the detection limit

Appendix C: Water temperature, dissolved oxygen and conductivity measurements at each station during mussel deployment and retrieval, Niagara River, 1997.
* meter was malfunctioning - interpret with caution

Sampling Station	Station number	Date	Water Temperature °C	Dissolved Oxygen (mg/L)	Conductivity at 25 °C
Canadian Sites					
Fort Erie at Robertson St.	(5-2)-203	17-Jul	22.8	10.9	277
		7-Aug	23.6	10.7	270
Black Creek (mouth)	(5-2)-191	17-Jul	23.8	9.2	285
		7-Aug	24.8	10.8	417
Chippawa Channel	(5-2)-51	17-Jul	23.1	10.1	273
		7-Aug	22.5	5.7	275
NOTL	(11-2)-9	17-Jul	23.2	9.8	274
		7-Aug	21.8	10.4	274
US Sites					
Buffalo River	(5-2)-196	18-Jul	24.0	6.7	320
		8-Aug	23.6	4.1	416
Tonawanda Channel (upstream of Two Mile Creek)	(5-2)-92	15-Jul	23.8	9.6	281
		5-Aug	23.5	5.4	280
Two Mile Creek (mouth)	(5-2)-197	15-Jul	25.9	10.5	955
		16-Jul	27.4	9.3	1080
		18-Jul	26.0	9.0	1036
		22-Jul	23.6	5.5	399
		5-Aug	22.7	5.5	500
Pettit Flume (upstream)	(5-2)-185	15-Jul	23.5	8.5	284
		5-Aug	23.2	8.8	281
Pettit Flume (site B)	(5-2)-186	15-Jul	25.6	12.4	410
		5-Aug	25.2	16.0	250
Gratwick/Riverside Park (upstream)	(5-2)-31	15-Jul	23.8	10.5	298
		5-Aug	23.4	9.0	281
Gratwick/Riverside Park	(5-2)-199	15-Jul	26.2	13.6	272
		16-Jul	24.7	11.1	277
		17-Jul	25.7	12.1	277
		18-Jul	24.7	10.0	281
		22-Jul	24.6	13.5	265
		29-Jul	24.8	12.6	432
		5-Aug	24.0	11.7	279
	*	12-Aug	24.1	11.5	275
		9-Sep	20.9	10.6	377
		21-Oct	15.1	11.2	275
		19-Nov	6.0	12.8	335
102nd Street (upstream)	(5-2)-93	15-Jul	24.9	13.2	275
		5-Aug	24.0	12.5	282
102nd Street	(5-2)-22	15-Jul	24.7	10.9	278
		16-Jul	25.3	10.5	279
		17-Jul	25.3	9.6	279
		18-Jul	24.7	8.6	284
		22-Jul	23.5	9.9	283
		29-Jul	23.1	9.7	289
		5-Aug	23.3	10.7	289
	*	12-Aug	22.3	8.4	292
		9-Sep	20.8	9.1	282
		21-Oct	13.2	10.8	283

Appendix C continued.

Sampling Station	Station number	Date	Water Temperature °C	Dissolved Oxygen (mg/L)	Conductivity at 25 °C
Cayuga Creek	(5-15)-31	15-Jul	25.7	7.9	950
		16-Jul	27.8	7.2	867
		17-Jul	26.7	6.7	861
		18-Jul	26.3	7.4	1020
		22-Jul	24.0	8.8	935
		29-Jul	24.9	12.9	1181
		5-Aug	23.8	8.9	793
	*	12-Aug	22.7	8.3	829
		9-Sep	20.1	8.1	680
		21-Oct	10.3	11.1	764
		19-Nov	2.0	10.8	1520
Upstream Sewer A	(5-2)-47	16-Jul	24.7	10.9	280
		6-Aug	23.3	10.4	283
Sewer A	(5-2)-46	16-Jul	24.4	10.6	280
		6-Aug	23.2	10.0	282
Sewer B	(5-2)-94	16-Jul	24.4	10.6	281
		6-Aug	23.4	9.9	281
Between Sewer B and Sewer C	(5-2)-45	16-Jul	24.7	10.6	280
		6-Aug	23.5	10.7	280
Sewer C	(5-2)-44	16-Jul	24.5	10.3	281
		6-Aug	23.0	8.4	282
Between Sewer C and Sewer 003	(5-2)-43	16-Jul	24.5	10.5	282
		6-Aug	23.5	10.2	281
Occidental Sewer 003	(5-2)-42	16-Jul	25.7	8.1	378
		6-Aug	26.1	8.0	299
Storm Sewer - S&N	(5-2)-40	16-Jul	24.8	10.3	335
		6-Aug	23.2	9.4	284
Gill Creek	(5-2)-37	16-Jul	23.4	8.2	284
		6-Aug	22.8	7.4	291
Bloody Run Creek (upstream)	(11-2)-18	16-Jul	21.9	10.0	279
		6-Aug	21.6	9.9	276
Bloody Run Creek (mouth)	(11-2)-17	16-Jul	21.6	10.0	280
		6-Aug	21.5	9.8	261

Appendix D: Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T:Measurable trace amount-interpret with caution.

BOW	STN TYPE	STN #	DATE YYMMDD	TIME	FIELD SAMPLE NUMBER	LIPID %	Aldrin NG/G W	RMK	a-BHC NG/G W	RMK	b-BHC NG/G W	RMK	g-BHC NG/G W	RMK	a-chlordane NG/G W	RMK	g-chlordane NG/G W	RMK	heptachlor NG/G W	RMK	mirex NG/G W	RMK	o'p-DDT NG/G W	RMK
5	2	203	970807	1410	GL778081	0.54	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	203	970807	1410	GL778082	0.56	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	203	970807	1410	GL778083	0.78	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	196	970808	1030	GL778084	0.71	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	196	970808	1030	GL778085	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	196	970808	1030	GL778086	0.69	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	191	970807	1245	GL778080	0.64	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	191	970807	1245	GL778078	0.6	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	191	970807	1245	GL778079	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	45	970806	1655	GL778070	0.73	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	45	970806	1655	GL778071	0.47	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	45	970806	1655	GL778069	0.67	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	9	970807	845	GL778072	0.47	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	9	970807	845	GL778073	0.33	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	9	970807	845	GL778074	0.89	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	51	970807	1220	GL778075	0.45	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	51	970807	1220	GL778076	0.87	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	51	970807	1220	GL778077	0.57	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	43	970806	1505	GL778057	0.59	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	43	970806	1505	GL778058	0.47	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	43	970806	1505	GL778059	0.73	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	94	970806	1530	GL778060	0.52	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	94	970806	1530	GL778061	0.63	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	94	970806	1530	GL778062	0.37	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	46	970806	1555	GL778063	0.34	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	46	970806	1555	GL778064	0.68	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	46	970806	1555	GL778065	0.47	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	47	970806	1615	GL778066	0.38	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	47	970806	1615	GL778067	0.51	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	47	970806	1615	GL778068	0.83	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	40	970806	1350	GL778048	0.6	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	15	<T	5	<=W
5	2	40	970806	1350	GL778049	0.48	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	10	<T	5	<=W
5	2	40	970806	1350	GL778050	0.42	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	10	<T	5	<=W
5	2	42	970806	1410	GL778051	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	20	<T	5	<=W
5	2	42	970806	1410	GL778052	0.75	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	20	<T	5	<=W
5	2	42	970806	1410	GL778053	0.75	1	<=W	6	<T	2	<T	1	<=W	2	<=W	2	<=W	1	<=W	20	<T	5	<=W
5	2	44	970806	1425	GL778054	0.78	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	44	970806	1425	GL778055	0.64	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	44	970806	1425	GL778056	0.67	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	37	970806	1320	GL778045	0.36	1	<=W	3	<T	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	37	970806	1320	GL778046	0.54	1	<=W	4	<T	2	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	37	970806	1320	GL778047	0.73	1	<=W	2	<T	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	31	970805	1905	GL778036	0.25	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	31	970805	1905	GL778037	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	31	970805	1905	GL778038	0.72	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	18	970806	945	GL778039	0.42	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	18	970806	945	GL778040	0.55	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	18	970806	945	GL778041	0.49	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	17	970806	950	GL778042	0.73	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W

P40: PCB resembled mixture of aroclor 1254 and 1260

Appendix D: Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T:Measurable trace amount-interpret with caution.

BOW	STN TYPE	STN #	DATE YYMMDD	TIME	FIELD SAMPLE	LIPID %	Aldrin NG/G W		a-BHC NG/G W		b-BHC NG/G W		g-BHC NG/G W		a-chlordane NG/G W		g-chlordane NG/G W		heptachlor NG/G W		mirex NG/G W		o'p-DDT NG/G W	
11	2	17	970806	950	GL778043	0.56	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
11	2	17	970806	950	GL778044	0.67	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	197	970805	1600	GL778021	0.53	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	197	970805	1600	GL778022	0.75	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	197	970805	1600	GL778023	0.5	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	92	970805	1650	GL778024	0.48	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	92	970805	1650	GL778025	0.42	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	92	970805	1650	GL778026	0.57	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	185	970805	1745	GL778030	0.42	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	185	970805	1745	GL778031	0.44	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	185	970805	1745	GL778032	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	186	970805	1805	GL778033	0.52	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	186	970805	1805	GL778034	0.63	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	186	970805	1805	GL778035	0.75	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	93	970805	1355	GL778012	0.61	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	93	970805	1355	GL778013	0.53	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	93	970805	1355	GL778014	0.65	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	15	31	970805	1505	GL778015	0.57	1	<=W	5	<T	6	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	15	31	970805	1505	GL778016	0.85	1	<=W	6	<T	5	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	15	31	970805	1505	GL778017	1.2	1	<=W	8	<T	8	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	199	970805	1530	GL778018	0.49	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	199	970805	1530	GL778019	0.66	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	199	970805	1530	GL778020	0.98	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	22	970805	1230	GL778009	0.88	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	22	970805	1230	GL778010	0.36	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W
5	2	22	970805	1230	GL778011	0.56	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W

P40: PCB resembled mixture of aroclor 1254 and 1260

Appendix D: Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T:Measurable trace amount-interpret with caution.

BOW	STN TYPE	STN #	PCB (total) NG/G W	RMK	photomirex NG/G W	RMK	p'p-DDD NG/G W	RMK	p'p-DDE NG/G W	RMK	p'p-DDT NG/G W	RMK	toxaphene NG/G W	RMK
5	2	203	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	203	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	203	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	196	20	<=W	4	<=W	6	<=W	2	<T	5	<=W	200	<=W
5	2	196	20	<=W	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
6	2	196	20	<=W	4	<=W	5	<=W	3	<T	6	<=W	200	<=W
5	2	191	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	191	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	191	20	<=W	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
5	2	45	40	P40	4	<=W	6	<=W	1	<=W	5	<=W	200	<=W
6	2	45	20	P40	4	<=W	5	<=W	1	<=W	6	<=W	200	<=W
6	2	45	40	P40	4	<=W	5	<=W	1	<=W	15	<T	200	<=W
11	2	9	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	9	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	9	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	51	20	<=W	4	<=W	5	<=W	2	<T	6	<=W	200	<=W
5	2	51	20	<=W	4	<=W	5	<=W	2	<T	6	<=W	200	<=W
5	2	51	20	<=W	4	<=W	6	<=W	2	<T	5	<=W	200	<=W
5	2	43	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	43	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	43	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
6	2	94	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	94	20	P40	4	<=W	6	<=W	1	<=W	5	<=W	200	<=W
6	2	94	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	46	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	46	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	46	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	47	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	47	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
6	2	47	40	P40	4	<=W	5	<=W	6	<T	6	<=W	200	<=W
5	2	40	60	P40	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	40	40	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	40	40	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	42	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
6	2	42	60	P40	4	<=W	5	<=W	8	<T	6	<=W	200	<=W
5	2	42	80	P40	4	<=W	5	<=W	1	<=W	6	<=W	200	<=W
5	2	44	40	P40	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	44	40	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	44	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	37	60	P40	4	<=W	5	<=W	1	<=W	6	<=W	200	<=W
5	2	37	80	P40	4	<=W	5	<=W	4	<T	6	<=W	200	<=W
5	2	37	60	P40	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
5	2	31	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	31	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	31	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	18	20	<=W	4	<=W	5	<=W	2	<T	6	<=W	200	<=W
11	2	18	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	18	20	<=W	4	<=W	5	<=W	1	<=W	6	<=W	200	<=W
11	2	17	40	P40	4	<=W	5	<=W	5	<T	5	<=W	200	<=W

P40: PCB resembled mixture of aroclor 1254 and 1260

Appendix D: Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T:Measurable trace amount-interpret with caution.

BOW	STN TYPE	STN #	PCB (total) NG/G W		photomirex NG/G W		p'p-DDD NG/G W		p'p-DDE NG/G W		p'p-DDT NG/G W		toxaphene NG/G W	
11	2	17	20	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
11	2	17	40	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	197	100	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	197	80	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	197	100	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	92	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	92	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	92	100	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	165	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	185	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	165	20	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	186	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	186	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	186	20	<=W	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	93	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	93	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	93	20	P40	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
5	15	31	40	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	15	31	60	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	15	31	60	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	199	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	199	40	P40	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	199	40	P40	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
5	2	22	40	P40	4	<=W	5	<=W	2	<T	5	<=W	200	<=W
5	2	22	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	22	20	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W

P40: PCB resembled mixture of aroclor 1254 and 1260

Appendix D:Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T measurable trace amount, interpret with caution.

BOW	STN TYPE	STN #	DATE YYMMDD	TIME	SMP TYPE	FIELD SAMPLE NUMBER	hexachloro-butadiene NG/G W		hexaCB NG/G W		hexachloro-ethane NG/G W		octachloro-styrene NG/G W		pentaCB NG/G W		236-trichloro toluene NG/G W		245-trichloro toluene NG/G W	
5	2	203	970807	1410	24	GL778081	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	203	970807	1410	24	GL778082	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	203	970807	1410	24	GL778083	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	191	970807	1245	24	GL778078	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	191	970807	1245	24	GL778079	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	191	970807	1245	24	GL778080	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	51	970807	1220	24	GL778075	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	51	970807	1220	24	GL778076	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	51	970807	1220	24	GL778077	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	9	970807	845	24	GL778072	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	9	970807	845	24	GL778073	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	9	970807	845	24	GL778074	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	92	970805	1650	24	GL778024	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	92	970805	1650	24	GL778025	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	92	970805	1650	24	GL778026	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	197	970805	1600	24	GL778021	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	197	970805	1600	24	GL778022	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	197	970805	1600	24	GL778023	1	<=W	2	<T	1	<=W	4	<T	1	<=W	1	<=W	1	<=W
5	2	185	970805	1745	24	GL778030	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	185	970805	1745	24	GL778031	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	185	970805	1745	24	GL778032	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	186	970805	1805	24	GL778033	1	<=W	10		1	<=W	1	<=W	13		1	<=W	3	
5	2	186	970805	1805	24	GL778034	1	<=W	17		1	<=W	1	<=W	12		1	<=W	1	<=W
5	2	186	970805	1805	24	GL778035	1	<=W	24		1	<=W	1	<=W	13		1	<=W	1	<=W
5	2	31	970805	1905	24	GL778036	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	31	970805	1905	24	GL778037	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	31	970805	1905	24	GL778038	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	199	970805	1530	24	GL778018	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W
5	2	199	970805	1530	24	GL778019	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W
5	2	199	970805	1530	24	GL778020	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W
5	2	93	970805	1355	24	GL778012	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	93	970805	1355	24	GL778013	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	93	970805	1355	24	GL778014	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	22	970805	1230	24	GL778009	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W
5	2	22	970805	1230	24	GL778010	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	22	970805	1230	24	GL778011	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	15	31	970805	1505	24	GL778015	1	<=W	2	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W
5	15	31	970805	1505	24	GL778016	1	<=W	2	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W
5	15	31	970805	1505	24	GL778017	1	<=W	3	<T	1	<=W	2	<T	2	<T	1	<=W	1	<=W
5	2	47	970806	1615	24	GL778066	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	47	970806	1615	24	GL778067	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	47	970806	1615	24	GL778068	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	46	970806	1555	24	GL778063	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	46	970806	1555	24	GL778064	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	46	970806	1555	24	GL778065	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	94	970806	1530	24	GL778060	2	<T	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W
5	2	94	970806	1530	24	GL778061	2	<T	2	<T	2	<T	1	<=W	3	<T	1	<=W	2	<T
5	2	94	970806	1530	24	GL778062	2	<T	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W
5	2	45	970806	1655	24	GL778069	1	<=W	2	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W
5	2	45	970806	1655	24	GL778070	1	<=W	2	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W
5	2	45	970806	1655	24	GL778071	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	44	970806	1425	24	GL778054	1	<=W	3	<T	1	<=W	1	<=W	4	<T	1	<=W	1	<=W
5	2	44	970806	1425	24	GL778055	1	<=W	2	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W
5	2	44	970806	1425	24	GL778056	1	<=W	3	<T	1	<=W	1	<=W	3	<T	1	<=W	2	<T

Appendix D:Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T measurable trace amount, interpret with caution.

BOW	STN TYPE	STN #	DATE YYMMDD	TIME	SMP TYPE	FIELD SAMPLE	hexachloro-butadiene		hexaCB		hexachloro-ethane		octachloro-styrene		pentaCB		236-trichloro toluene		245-trichloro toluene	
6	2	43	970806	1505	24	GL778067	2	<T	2	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W
5	2	43	970806	1505	24	GL778058	2	<T	3	<T	2	<T	1	<=W	3	<T	1	<=W	1	<=W
5	2	43	970806	1605	24	GL778059	2	<T	2	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W
5	2	42	970806	1410	24	GL778051	11		27		2	<T	20		10		3	<T	3	<T
5	2	42	970806	1410	24	GL778052	9	<T	32		1	<=W	23		12		4	<T	4	<T
5	2	42	970806	1410	24	GL778053	9	<T	21		1	<=W	20		9	<T	5	<T	7	<T
5	2	40	970806	1350	24	GL778048	6	<T	9	<T	2	<T	6	<T	4	<T	1	<=W	1	<=W
5	2	40	970806	1350	24	GL778049	5	<T	13		1	<=W	3	<T	7	<T	2	<T	1	<=W
6	2	40	970806	1350	24	GL778050	6	<T	9	<T	1	<=W	3	<T	4	<T	1	<=W	1	<=W
5	2	37	970806	1320	24	GL778045	160		3	<T	8	<T	1	<=W	2	<T	1	<=W	1	<=W
5	2	37	970806	1320	24	GL778046	160		3	<T	2	<T	1	<=W	2	<T	1	<=W	1	<=W
5	2	37	970806	1320	24	GL778047	120		3	<T	2	<T	1	<=W	2	<T	1	<=W	1	<=W
11	2	18	970806	946	24	GL778039	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	18	970806	945	24	GL778040	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	18	970806	945	24	GL778041	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
11	2	17	970806	950	24	GL778042	3	<T	13		1	<=W	1	<=W	10		4	<T	1	<=W
11	2	17	970806	950	24	GL778043	3	<T	11		1	<=W	1	<=W	8	<T	3	<T	1	<=W
11	2	17	970806	950	24	GL778044	3	<T	11		1	<=W	1	<=W	7	<T	3	<T	1	<=W
5	2	196	970808	1030	24	GL778084	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	196	970808	1030	24	GL778086	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W
5	2	196	970808	1030	24	GL778086	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W

Appendix D:Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T measurable trace amount, interpret with caution.

BOW	STN TYPE	STN #	123-triCB NG/G W		1234-tetra CB NG/G W		1235-tetra CB NG/G W		124-triCB NG/G W		1245-tetra CB NG/G W		135-triCB NG/G W	
5	2	203	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	203	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	203	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	191	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	191	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	191	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	51	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
6	2	51	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	51	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	9	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	9	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	9	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	92	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	92	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	92	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	197	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	197	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	197	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	185	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	185	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	185	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	186	4	<T	7	<T	3	<T	2	<=W	4	<T	4	<T
5	2	186	2	<=W	6	<T	3	<T	2	<=W	4	<T	4	<T
5	2	186	2	<=W	5	<T	3	<T	2	<=W	4	<T	4	<T
5	2	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	199	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	199	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	199	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	93	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
6	2	93	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	93	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	22	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	22	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	22	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
6	15	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	15	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	15	31	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	47	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	47	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	47	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	46	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	46	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
6	2	46	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	94	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	94	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	94	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	45	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
6	2	45	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	45	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	44	2	<=W	3	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	44	2	<=W	1	<=W	1	<=W	14	<T	1	<=W	2	<=W
5	2	44	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W

Appendix D:Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1997. <W: no measurable response. <T measurable trace amount, interpret with caution.

BOW	STN TYPE	STN #	123-triCB		1234-tetra CB		1235-tetra CB		124-triCB		1245-tetra CB		135-triCB	
5	2	43	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	43	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	43	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	42	2	<=W	9	<T	1	<=W	2	<=W	17	<T	2	<=W
5	2	42	2	<=W	9	<T	1	<=W	2	<=W	20	<T	2	<=W
5	2	42	2	<=W	8	<T	1	<=W	2	<=W	29	<T	2	<=W
5	2	40	2	<=W	3	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	40	2	<=W	5	<T	1	<=W	2	<=W	9	<T	2	<=W
5	2	40	2	<=W	4	<T	1	<=W	2	<=W	1	<=W	2	<=W
5	2	37	2	<=W	1	<=W	1	<=W	2	<=W	7	<T	12	<T
5	2	37	2	<=W	1	<=W	1	<=W	2	<=W	8	<T	12	<T
5	2	37	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	10	<T
11	2	18	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	18	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	18	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
11	2	17	2	<=W	3	<T	3	<T	2	<=W	1	<=W	2	<=W
11	2	17	2	<=W	3	<T	2	<T	2	<=W	1	<=W	2	<=W
11	2	17	2	<=W	2	<T	2	<T	2	<=W	1	<=W	2	<=W
5	2	196	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
5	2	196	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
6	2	196	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W

KEY TO PAH POLLUTANT ABREVIATIONS

NAME	CODE
Acenaphthene	PNACNE
Acenaphthylene	PNACNY
Anthracene	PNANTH
Benzo(a)anthracene	PNBAA
Benzo(a)pyrene	PNBaP
Benzo(b)fluoranthene	PNBBFA
Benzo(k)fluoranthene	PNBKF
Chrysene	PBCHRY
Dibenzo(a,h)anthracene	PNDAHA
Fluoranthene	PNFLAN
Fluorene	PNFLUO
Benzo(g,h,i)perylene	PBGHIP
Indeno(1,2,3-c,d)pyrene	PBINP
Naphthalene	PNNAPH
Phenanthrene	PNPHEN
Pyrene	PNPYR

Appendix D: Concentrations of polycyclic aromatic hydrocarbons in caged mussels introduced to the Niagara River, 1997. <W:no measurable response. <T measurable trace amount - interpret with caution.

BOW	STN TYPE	STN #	DATE YYMMDD	TIME	SMP TYPE	FIELD SAMPLE NUMBER	D10PHE UNIT NF	D12CHR UNIT NF	D8NAPH UNIT NF	PNACNE NG/G W	RMK	PNACNY NG/G W	RMK	PNANTH NG/G W	RMK	PNBAA NG/G W	RMK	PNBAP NG/G W	RMK	PNBBFA NG/G W	RMK	PNBKF NG/G W	RMK
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5	2	22	970805	1230	24	GL778009	69	77	45	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	22	970805	1230	24	GL778010	68	73	46	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	22	970805	1230	24	GL778011	73	74	45	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	93	970805	1355	24	GL778012	78	96	47	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	93	970805	1355	24	GL778013	82	99	63	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	93	970805	1355	24	GL778014	67	75	34	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	197	970805	1600	24	GL778021	62	71	34	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	80	<T	20	<=W
5	2	197	970805	1600	24	GL778022	55	52	30	20	<=W	20	<=W	20	<=W	40	<T	40	<=W	80	<T	40	<T
5	2	197	970805	1600	24	GL778023	77	93	50	20	<=W	20	<=W	20	<=W	40	<T	40	<=W	60	<T	20	<=W
5	2	92	970805	1650	24	GL778024	89	110	0	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	92	970805	1650	24	GL778025	89	130	99	40	<T	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	92	970805	1650	24	GL778026	95	150	130	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	186	970805	1805	24	GL778033	88	220	120	20	<=W	20	<=W	20	<=W	100		40	<=W	20	<=W	20	<=W
5	2	186	970805	1805	24	GL778034	92	170	98	20	<=W	20	<=W	20	<=W	80	<T	40	<=W	20	<=W	20	<=W
5	2	186	970805	1805	24	GL778035	90	150	110	20	<=W	20	<=W	20	<=W	100		40	<=W	20	<=W	20	<=W
11	2	9	970807	845	24	GL778072	93	130	140	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
11	2	9	970807	845	24	GL778073	80	160	100	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
11	2	9	970807	845	24	GL778074	110	220	140	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	51	970807	1220	24	GL778075	99	180	130	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	51	970807	1220	24	GL778076	100	150	140	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	51	970807	1220	24	GL778077	130	200	140	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	203	970807	1410	24	GL778081	71	140	92	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	203	970807	1410	24	GL778082	88	120	100	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	203	970807	1410	24	GL778083	91	120	100	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	196	970808	1030	24	GL778084	100	140	120	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	196	970808	1030	24	GL778085	78	100	85	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W
5	2	196	970808	1030	24	GL778086	78	120	100	20	<=W	20	<=W	20	<=W	20	<=W	40	<=W	20	<=W	20	<=W

Appendix D: Concentrations of polycyclic aromatic hydrocarbons in caged mussels introduced to the Niagara River, 1997. <W:no measurable response. <T measurable trace amount - interpret with caution.

BOW	STN TYPE	STN #	PNCHRY NG/G W	RMK	PNDAHA NG/G W	RMK	PNFLAN NG/G W	RMK	PNFLUO NG/G W	RMK	PNGHIP NG/G W	RMK	PNINP NG/G W	RMK	PNNAPH NG/G W	RMK	PNPHEN NG/G W	RMK	PNPYR NG/G W	RMK
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5	2	22	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	22	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	22	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	93	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	93	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	93	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	197	180		40	<=W	220		20	<=W	40	<=W	40	<=W	20	<=W	60	<T	160	
5	2	197	220		40	<=W	280		20	<=W	40	<=W	40	<=W	20	<=W	80	<T	200	
5	2	197	160		40	<=W	200		20	<=W	40	<=W	40	<=W	20	<=W	60	<T	140	
5	2	92	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	92	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	92	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	186	600		40	<=W	420		20	<=W	120	<T	40	<=W	20	<=W	180		260	
5	2	186	520		40	<=W	340		20	<=W	120	<T	80	<T	20	<=W	120		220	
5	2	186	500		40	<=W	440		20	<=W	160	<T	80	<T	20	<=W	160		300	
11	2	9	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
11	2	9	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
11	2	9	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	51	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	51	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	51	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	203	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	203	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	203	20	<=W	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	196	40	<T	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	196	40	<T	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	20	<=W
5	2	196	60	<T	40	<=W	20	<=W	20	<=W	40	<=W	40	<=W	20	<=W	20	<=W	40	<T